MINERALOGY OF KENTUCKY

CHARLES HENRY RICHARDSON

The

Kentucky Geological Survey

WILLARD ROUSE JILLSON
DIRECTOR and STATE GEOLOGIST

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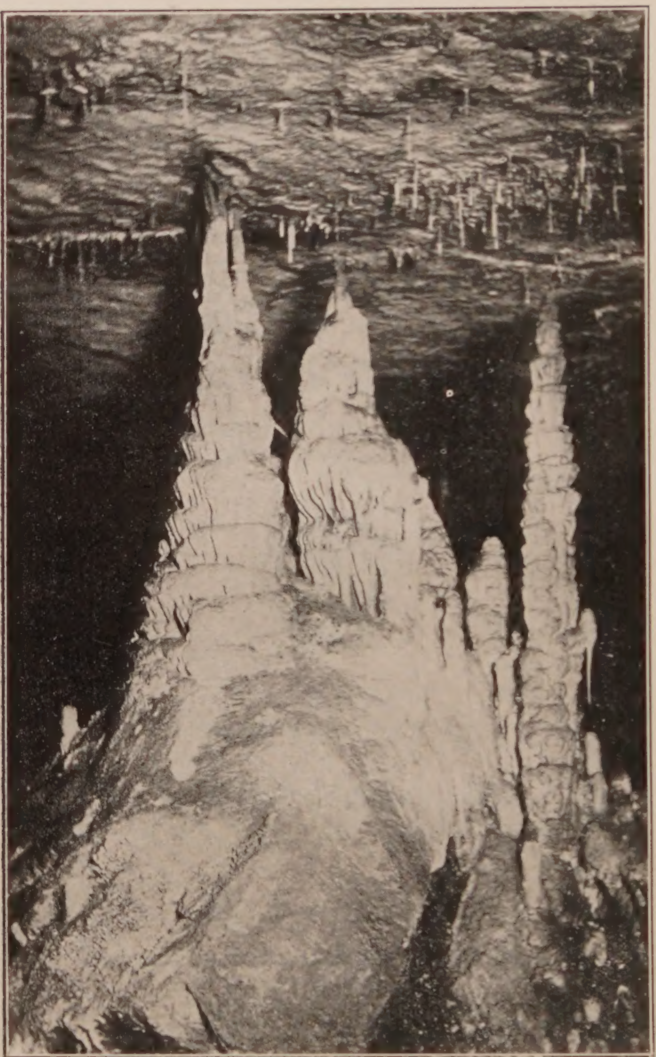

KENTUCKY STALACTITE AND STALAGMITE.

Mineralogical formations of this character are well developed in and typical of many of the limestone caverns of Kentucky. These uniquely symmetrical columns occur in the Great Onyx Cave, near Mammoth Cave and Green River in Edmonson County, Kentucky.

LETTER OF TRANSMISSION

Professor Willard Rouse Jillson,
Director and State Geologist,
The Kentucky Geological Survey,
Frankfort, Kentucky.

Dear Sir:

Permit me to transmit herewith my illustrated manuscript entitled the Mineralogy of Kentucky.

The field work for the preparation of this report was done during the summers of 1920, 1921, 1922, 1923, and a part of 1924. The laboratory work was carried out in the laboratories of the Department of Mineralogy at Syracuse University, Syracuse, N. Y., during each of the intervening academic years.

An effort has been made to describe every known mineral indigenous to Kentucky but no effort is made to include the essential and accessory constituents of erratics. It is hoped that this work will add materially to the knowledge of minerals native to Kentucky.

Respectfully submitted,

CHARLES H. RICHARDSON,
Assistant Geologist.

Frankfort, Ky.,
August 22, 1924.

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PREFACE

Within recent years the interest of the public in mineral resources has grown measureably. This has been particularly true in Kentucky where so great a part of the undeveloped wealth of the Commonwealth exists in this form. At the present time, perhaps moreso than ever in the past, residents of those parts of this State in which large bodies of mineral are known to exist though frequently unmapped and undeveloped are evincing a lively interest in systematic scientific investigations of these various deposits.

Though not a little has been written and published by the several Geological Surveys of Kentucky since Dr. William Williams Mather made his first official reconnaissance of Kentucky in 1838, nothing has appeared that could in any way be considered a full statement concerning the minerals found in this State. Such a work this volume purports to be. Its author Dr. Charles Richardson needs no introduction to Kentuckians as he is well known throughout this State by reason of his several geological investigations for the Kentucky Geological Survey during recent years.

Old Capitol,

W. R. Jillson

Frankfort, Ky.,
June 1, 1925.

Director and State Geologist,
Kentucky Geological Survey.

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MINERALOGY OF KENTUCKY

CHAPTER I.

INTRODUCTION

The field work upon which this report is based was done during the summers of 1920, 1921, 1922 and 1923 in conjunction with other geological investigations now published. In the mineralogical and petrographic studies some minerals hitherto unknown in Kentucky were discovered. The minerals described in this report are only those occurring within the Commonwealth of Kentucky as native minerals. The purpose of this treatise is to bring all the information that is available concerning minerals found native in Kentucky into a concise form and render it of service to those interested in the practical and scientific investigation of these resources in this great Commonwealth.

In addition to the classification of minerals as they appear in the numerous textbooks on mineralogy, the minerals of Kentucky naturally divide themselves into three classes:

1—Those occurring as economic possibilities within the State.
2—Those that do not occur in quantities adequate for economic production within the Commonwealth of Kentucky, or as yet have no known economic use.
3—The mineralloids. These products do not possess all the characteristics suggested in the definition of a mineral, as given a little later in this work, but they are always included in such works as the *Mineral Resources of the United States*, and *The Mineral Industry. Its Statistics, Technology, and Trade.* The mineralloids are therefore, mineral-like products. They are of organic rather than of inorganic origin. They should not be omitted in this work, for they constitute a very important contribution to the mineral wealth of the State.

The more logical method of treatment in this terse work is as follows:

1—The metallic minerals.
2—The non-metallic minerals.
3—The mineralloids.

The metallic minerals are treated in the order of their group separation as given in qualitative analysis. The non-metallic minerals are treated in a logical order with the alkaline earths and alkalies as they appear in qualitative analysis, followed by silica and the silicates. The order of treatment of the silicates is that followed by J. D. Dana in his Manual of Mineralogy.

Chapter II comprises a study of the morphological properties of minerals. It defines the six systems of crystallization showing the position of the axes and planes of symmetry, but it makes no attempt to describe the thirty-two different classes of crystals into which minerals through their crystallographic forms may be divided.

Chapter III embraces a study of the physical properties of minerals, i. e., those relating to the behavior of physical forces upon these natural inorganic elements or compounds. It is the field most easily understood by the student beginning the study of minerals and the one largely used in descriptive mineralogy in our various colleges and universities. It is advantageous but not necessary for the reader to have a knowledge of chemistry.

Chapter IV embraces the chemical properties of minerals, i. e., those relating to the composition and the behavior of wet and dry reagents upon minerals. Certain minerals may be easily identified by their physical properties, especially when their crystallizing force is strong, while others demand chemical reactions for their positive identification. All the tests given can be applied and understood by any student who has had a course in elementary chemistry.

Chapter V cites a large number of useful blowpipe tests that may be applied in the identification of minerals both common and rare. It does not require an expensive equipment to carry out this work. An alcohol lamp may replace the Bunsen burner, a bent glass tube the blowpipe, and a piece of common charcoal can be used.

CHAPTER II.

THE PROPERTIES OF MINERALS

A mineral is an inorganic substance occurring in nature with a fairly definite chemical composition. It usually possesses a definite crystalline structure which sometimes finds expression in external geometrical forms and outlines. In a broader sense, which is subject to some criticism, the term mineral has been made to include such organic products as whewellite, CaC_2O_4, H_2O, which crystallizes in prismatic forms in the monoclinic system. Such products are better classified with the mineralloids, for they are salts of organic acids.

Mineralogy is the study or science which treats of the properties and uses of minerals. Its purpose is to enable one to quickly identify such economic minerals as he is likely to meet, to cultivate his powers of observation, discrimination, and accuracy, and to acquaint oneself with the mineral wealth of the world.

PROPERTIES OF MINERALS

The properties of minerals fall into three distinct classes:

1—*Morphological*:—Those relating to form and structure. This field is of vital importance in the study of crystallography.

2—*Physical*:—Those relating to the action of physical forces on minerals. Purely descriptive mineralogy deals largely with the response of minerals to these physical agents.

3—*Chemical*:—Those relating to the composition of minerals, their oxidation, reduction, sublimation, fusion, and the behavior of mineral acids upon them.

MORPHOLOGICAL PROPERTIES

A crystal may be defined as a natural solid bounded by plane surfaces. There are 66 possible geometrical forms of crystals which are referable to 6 different systems of crystallization. Furthermore, these forms may be divided into 32 distinct classes.

The six systems may be tersely defined as follows:

1—*The Isometric System.* This system comprises all forms whose planes are referable to three axes that intersect each other at right angles and are always equal and interchangeable; example, galenite, PbS, the most important ore of lead.

The symmetry of the system is nine-fold. It contains three principal planes of symmetry at right angle to each other. The angles between these principal planes are bisected by six secondary planes of symmetry.

2—*The Tetragonal System.* This system comprises all forms whose planes are referable to three axes intersecting each other at right angles, but with a vertical axis either longer or shorter than the lateral. The lateral axes are equal and interchangeable; example, cassiterite, SnO_2, the most important ore of tin.

This system contains one principal plane of symmetry which is intersected by four secondary planes of symmetry. Two of these are called the axial planes, and intersect each other at right angles. The other two are called the intermediate planes.

3—*The Hexagonal System.* This system comprises all forms whose planes are referable to three lateral axes intersecting each other at 60 or 120 degrees, always equal and interchangeable, and a vertical axis which intersects the lateral axes at right angles. The vertical axes may be either longer or shorter than the lateral axes; example, quartz, SiO_2, the commonest of all known minerals.

This system contains one principal plane of symmetry and six vertical secondary planes which intersect each other at angles of 30 degrees. These secondary planes are subdivided into three axial and three intermediate vertical planes.

4—*The Orthorhombic System.* This system comprises all forms whose planes are referable to three unequal and uninterchangeable axes which intersect each other at right angles; example, barite, $BaSO_4$, which is found in the limestones of the Inner Bluegrass Region.

This system has no principal plane of symmetry, but it has three secondary planes of symmetry which are perpendicular to each other and always of unequal length.

5—*The Monoclinic System.* This system comprises all forms whose planes are referable to three unequal and uninterchangeable axes. One of the two lateral axes is inclined to the vertical; example, orthoclase, $K_2O,Al_2O_3,6SiO_2$, the most important member of the feldspar family.

This system has but one plane of symmetry. This plane is at right angle to the longer of the two lateral axes.

6—*The Triclinic System.* This system comprises all forms whose planes are referable to three unequal and uninterchangeable axes, each of which is inclined to the other two; example, albite, $Na_2O,Al_2O_3,6SiO_2$, the most common representative of the plagioclase division of the feldspar family.

This system has no principal plane of symmetry and no secondary plane of symmetry. The presence of any face of a crystal in this system demands only the presence of an opposite parallel face.

Degrees of Crystallization

1—*Crystallized.* Several minerals occur in well developed isolated crystals or in groups of crystal aggregates. The geometric form of the mineral can be easily determined. Examples, calcite, fluorite, and quartz have a strong crystallizing force and are, therefore, prone to appear in well defined crystals.

2—*Crystalline.* Many minerals occur in a massive crystalline form devoid of plane surfaces that may be determined by the naked eye. Magnetite, an important ore of iron, is often massive and crystalline. The statuary marble of Carrara, Italy, is an example of a crystalline aggregate.

3—*Cryptocrystalline.* Some minerals appear to the naked eye to be amorphous, that is, without form, but in reality they are microscopically crystalline; example, the chalcedonic varieties of quartz.

4—*Amorphous.* Certain minerals exist as colloids or gels. They do not crystallize because the tendency to assume definite geometric form is too weak to permit crystallization; therefore, they form only amorphous masses. Example, limonite, $2Fe_2O_3,3H_2O$, an important ore of iron.

EXTERNAL FORMS

The external form of a mineral is often an important guide in its identification. Minerals are frequently well crystallized and their geometric form easily determined. Most minerals occur in crystalline aggregates, of which there are many types. A few occur as amorphous masses. The following glossary of external forms will be helpful in the identification of the minerals occurring within the Commonwealth of Kentucky. The glossary is arranged in alphabetical order, that the reader may more readily find the particular structure cited.

1—*Acicular.* When the crystals are delicate and needle-like. Often they radiate from a common center. Example, natrolite.

2—*Amygdaloidal.* This term refers to the almond-shaped cavities that often occur in the basic igneous rocks. The cavities may be either partly or entirely filled with secondary mineral matter. If the cavity is completely filled, then the mineral mass is itself almond-shaped. Example, several of the zeolites of Nova Scotia.

3—*Arborescent.* When the mineral matter forms in tree-like aggregates. Example, native copper, native silver.

4—*Bladed.* When columnar or prismatic crystals are flattened so as to present the appearance of a knife blade. They may also be elongated in parallel or divergent forms. Example cyanite.

5—*Botryoidal.* When the mineral mass closely resembles a bunch of grapes. Example, chalcedony.

6—*Capillary.* When the crystals occur in fine hair-like threads. Example, rutile in quartz crystals.

7—*Columnar.* When the mineral matter appears in coarse fibers or columns which are often grouped in parallel positions. Example, basalt from the Giant's Causeway, Ireland.

8—*Concentric.* When the mineral matter arranges itself in spherical layers around a common center, similar to the layers of an onion. Example, agate from Brazil.

9—*Concretionary.* When the mineral matter appears in rounded or nodular masses. Example, clay iron stone of Syracuse, N. Y.

10—*Cruciform.* When the crystals are arranged in the form of a cross. Example, staurolite.

11—*Cyclic.* When by repeated twinning crystals produce circular forms. Example, aragonite.

12—*Dendritic.* When the mineral matter arranges itself in the form of a fern. Example, pyrolusite.

13—*Divergent.* When the crystals or fibres diverge from a common center. Example, pectolite.

14—*Drusy.* When the ends of minute, closely crowded crystals appear on the surface. Example, quartz.

15—*Efflorescent.* When the mineral matter appears as a thin crust or scum upon the surface. The efflorescence of some soluble salt is often seen on the surface of public buildings. Example, epsomite.

16—*Felted.* When the mineral fibers are closely matted together. Example, uralite.

17—*Fibrous.* When the mineral consists of slender fibers or threads. Example, serpentine var, chrysotile.

18—*Foliated.* When the mineral matter arranges itself in thin plates or leaves that separate easily. Example, talc.

19—*Geodetic.* When large cavities are formed within the mineral mass. Example, quartz geode, Keokuk, Iowa.

20—*Globular.* When the mineral appears in spherical or nearly spherical forms. Example, thompsonite.

21—*Hepatic.* When the mineral occurs in liver-shaped masses, Example, cinnabar, from California.

22—*Hopper Shaped.* When the mineral occurs in cavernous, tapering, and square funnel forms. Example, halite.

23—*Incrustation.* When one mineral occurs as a coating or crust upon another. Example, millerite, the sulphide of nickel, often incrusts some sulphide of iron.

24—*Lamellar*. When the mineral occurs in thin plates or layers. Example, barite.

25—*Lenticular*. When the mineral arranges itself in lens-shaped forms. Example, biotite, Craftsbury, Vt.

26—*Mammillary*. When the mineral arranges itself in rounded forms larger than grapes. Example, pyrolusite.

27—*Micaceous*. When the mass is made up of minute scales separable into extremely thin layers like the micas. Example, hematite, in Northern New York.

28—*Nodular*. When the mineral occurs in rounded masses of more or less irregular shape. Example, celestite, from Texas.

29—*Nugget*. When the mineral occurs in small, irregular masses, more or less rounded. Example, gold.

30—*Oolitic*. When the grains are about the size of the egg of a brook trout. Examples, hematite from central New York and the limestone from Bowling Green, Kentucky.

31—*Pisolitic*. When the mineral grains are rounded masses about the size of a pea. Example, bauxite, France.

32—*Plumose*. When the minute scales of minerals arrange themselves in forms suggesting a feather, Example, muscovite.

33—*Prismatic*. When crystals occur elongated, parallel to one of the crystallographic axes, usually the vertical axis. Example actinolite.

34—*Reinform*. When the mineral appears in rounded forms suggesting the shape of a kidney. Example, hematite.

35—*Radiating*. When the crystals diverge from a common center. Example, wavellite.

36—*Reticulated*. When the crystals cross each other like the meshes of a net. Example, stibnite.

37—*Sheaflike*. When the mineral matter is arranged in the form of a sheaf of wheat. Example, stilbite.

38—*Stalactitic.* When the mineral in cylindrical form hangs pendant from the roof of a cave like an icicle. Example, calcite var. stalactite.

39—*Stalagmitic.* When the mineral is built up in cylindrical forms on the floor of a cave. Example, calcite var. stalagmite.

40—*Tabular.* When the mineral arranges itself in flat, table-like forms. Example, barite.

INTERNAL STRUCTURE

1—*Granular.* When the substance consists of closely packed grains, either fine or coarse. Example, statuary marble.

2—*Compact.* When the minute grains invisible to the naked eye are closely and firmly united. The granular structure may be revealed by the microscope. Example, Manlius limestone, Syracuse, N. Y.

3—*Glassy.* When no trace of the granular structure can be detected, either by the eye or by the microscope. Example, obisidian.

CHAPTER III.

PHYSICAL PROPERTIES

A study of the physical properties of minerals forms the basis of work in purely descriptive mineralogy. A knowledge of these properties is necessary in the rapid determination of common minerals. To become familiar with minerals by this field of investigation does not stipulate the prerequisite of any other science, although some knowledge of each of the other sciences would be helpful in the work. As an aid to the reader the common physical properties of minerals will be defined. subdivisions given, and illustrations cited.

1—*Color.* Color is the quality of light reflected by a mineral. It answers the question what kind of light is reflected. The entire range of color seems represented in the mineral kingdom. Some minerals have constant colors like sulphur and therefore are idiochromatic, while others may embrace several if not all of the primary colors, as quartz, and therefore are dichromatic or polychromatic.

(a) Red, the color of realgar, As_2S_2, vermillion.
(b) White, the color of the alkaline earths and the alkalies, barite, $BaSO_4$.
(c) Blue, the color of chalcanthite, or blue vitriol, $CuSO_4$, $5H_2O$.
(d) Black, the color of magnetite, Fe_2O_3,FeO.
(e) Yellow, the color of sulphur, S.
(f) Green, the color of malachite, or malachite green paint, $CuCO_3$,$Cu(OH)_2$.
(g) Gray, the color of graphite, C, a dark steel gray mineral.

2—*Luster.* Luster is the quality and the quantity of light reflected by a mineral. It not only asks the question what kind of light is reflected but also how much light. Most minerals possess a standard luster as galenite, PbS, which always has a metallic luster, while others may have one luster for the mass of the mineral and another luster on some cleavage plane as albite, Na_2O, Al_2O_3,$6SiO_2$.

(a) Metallic. The luster of all metals and most of the sulphides of the metals, as gold, Au, and stibnite, Sb_2S_3.

(b) Sub-metallic. This is an imperfect metallic luster, as is often observed on hausmannite, Mn_2O_3,MnO.

(c) Adamantine. The luster of the diamond, C. It is an exceedingly brilliant luster.

(d) Vitreous. The luster of broken glass, or the crystalline varieties of quartz, as a quartz crystal, SiO_2.

(e) Resinous. The luster or appearance of fossil resins, as copalite, or cadmiferous sphalerite, ZnS.

(f) Greasy. The face of the mineral presents the appearance of an oiled surface as nephelite, var. elaeolite which is abundant in the elaeolite syenite of Ontario, Canada.

(g) Pearly. This luster suggests the interior of the shell of a pearl clam. It is well pronounced on the cleavage plane of the zeolite, heulandite, and on the curved faces of the rhombohedrons of dolomite, $CaCO_3,MgCO_3$.

(h) Silky. The luster of silk. It is due to a finely fibrous structure in the mineral as in serpentine var. chrysotile, $2H_2O,3MgO,2SiO_2$.

(i) Satiny. The luster of satin. The delicately fine fibers possess the color of satin, as in gypsum, var. satin spar, $CaSO_4 2H_2O$, where the fibres are set transversely to the bedding of the gypsiferous shales in which the crystals occur.

(j) Dull or earthy. There are no bright shining faces, for the luster is reduced to zero. In reality it is an absence of luster, as observed in chalk, $CaCO_3$ and kaolinite, $2H_2O,Al_2O_3,2SiO_2$.

The terms glimmering, glistening, shining, splendent, are sometimes used to represent the intensity of the luster.

3—*Streak.* The streak of a mineral is the color of the fine powder produced by some abrasive as a piece of broken porcelain or novaculite from Arkansas. The color of the streak of minerals is far more constant than the color of the minerals themselves. Therefore, the color of the streak of a mineral is not necessarily the color of the mineral itself. The streak of all white minerals is white, but the streak of all black minerals is not black. Quartz var. cairngorm is often black or nearly black, but its streak is white.

(a) Scarlet, the streak of cinnabor HgS.
(b) White, the streak of the alkaline earths, and the alkalies, calcite, $CaCO_3$.
(c) Blue, the streak of azurite, $2CuCO_3,Cu(OH)_2$.
(d) Black, the streak of magnetite, Fe_2O_3,FeO.
(e) Yellow, the streak of zincite, ZnO.
(f) Green, the streak of malachite, $CuCO_3,Cu(OH)_2$.
(g) Gray, the streak of native lead, Pb.

4—*Hardness.* Hardness is the resistance of a mineral to abrasion. Mohs's scale of hardness is generally used in making the comparative tests. It consists of ten minerals arranged in order of increasing resistance to abrasion. Each mineral in the series will abrade all the preceding minerals and be abraded by all that follow it. The scale in the order suggested is as follows:

1—Talc
2—Gypsum var. selenite
3—Calcite
4—Fluorite
5—Apatite
6—Orthoclase
7—Quartz
8—Topaz
9—Corundum
10—Diamond

1—Talc is easily reduced to a powder between the fingers.

2—Gypsum, var. selenite, is easily abraded by the thumb nail. The attempt should be made to plow a narrow furrow in the gypsum by pushing the edge of the nail along the gypsum plates or across them.

3—Calcite is not scratched by the thumb nail but is abraded by a penny.

4—Fluorite is not scratched by a copper coin but is easily abraded by a knife.
5—Apatite is cut with some difficulty by a pocket knife, depending somewhat upon the hardness of the steel in the blade.
6—Orthoclase will abrade the ordinary knife blade but faint traces of the mark of a manganese file may be seen on the edges of feldspar crystals.
7—Quartz abrades glass easily.
8—Topaz is abraded only by corundum, emery and the diamond. Emery is a little inferior in hardness to the crystallized corundum.
9—Corundum is abraded only by the diamond.
10—The diamond is abraded by its own dust and the crystalline variety of the diamond known as bort.

If a mineral is 6.5 in hardness it signifies that the mineral scratches orthoclase and is in turn scratched by quartz with approximately the same ease that it abraded orthoclase.

Beryl with a hardness according to the above scale of 6.75 is sometimes substituted for the less common mineral topaz. It should be remembered that there is a greater difference in hardness between corundum and the diamond than there is between talc and corundum. Bort, the imperfectly crystallized variety of the diamond, is harder than the gem itself.

5—*Specific gravity.* The specific gravity of a mineral is its weight compared with the weight of an equal volume of water. In determining the specific gravity, a fragment of the mineral about the size of a pea, is weighed in air in the upper scale pan and the weight recorded. The mineral is then transferred to the lower scale pan and weighed in water. This weight is also recorded.

Example—
Let X = the sp. gr. of the mineral.
Let W = the weight of the mineral in air.
Let W^1 = the weight of the mineral in water.

$$\text{Then } X = \frac{W}{W - W^1}$$

The weight in water is simply subtracted from the weight in air and the weight in air divided by the difference.

Minerals that closely resemble each other in color and crystal form often may be readily distinguished by their specific gravity. Thus barite has a sp. gr. of 4.6 but celestite has a sp. gr. of 3.96. Both are heavy minerals. Several different forms of balances are in use. The Jolly balance is the most expensive and easily worked. Only two readings and a single division are necessary to determine the specific gravity of an insoluble mineral.

The specific gravity is often determined by the weight of the water displaced by a mineral. This method is often used in determining the specific gravity of building stone and road building materials.

6—*Magnetism.* Magnetism is the property of a mineral whereby it is influenced when in the field of a magnet. It may be due to some peculiar molecular arrangement.

Only a few minerals are magnetic before heating. Meteoric iron is strongly magnetic. Native cobalt and nickel are somewhat magnetic. Magnetite, Fe_2O_3, FeO, is the most strongly magnetic of all compounds. Troilite, FeS, which occurs in meteorites is quite strongly magnetic. The magnetism of $(Fe,Mn,Zn)\ O$, $(Fe,Mn)_2\ O_3$ and pyrrhotite, Fen,Sn+1, varies widely. All compounds of iron, cobalt and nickel with volatile acid radicles become magnetic after heating. Iron and nickel lose their magnetism at high temperatures but pick it up again upon cooling. Cobalt retains its magnetism at high temperatures.

7—*Cleavage.* Cleavage is the natural parting of a mineral due to structure. These planes of parting are parallel to crystal faces. Cleavages are often conspicuous and characteristic. This property is the most highly developed in the flexible micas. Muscovite, known as the white mica, and the potash mica, can be separated by purely mechanical means into layers one fifteen hundredth of a millimeter in thickness.

By placing the sharp edge of a knife blade parallel with the face of a rhombohedron of calcite, $CaCO_3$, and striking the blade a gentle blow with a hammer, the mineral may be easily split down into very minute rhombohedrons. The cleavage of galenite, PbS, is so highly perfect and parallel with the faces of a cube that when the mineral has been broken down on the bucking board with a muller, and pulverized so that it passes through a 40-mesh sieve, cubical crystals of galenite with their high metallic luster can be observed in the powder.

Cleavage is expressed in two ways:

1—According to the ease with which it is obtained and the character of the faces revealed.

2—According to the direction.

In 1, the cleavages are expressed as perfect, as in the various members of the flexible micas when the cleaved face is smooth and perfect.

The cleavage is imperfect when the faces cleaved are somewhat roughened as in tourmaline.

The cleavage is interrupted when the surface is more or less roughened and the planes obtained only with difficulty as in staurolite.

Cleavage is wanting in all minerals that have no crystal system, and no crystal form, as bauxite, $Al_2O_3,2H_2O$, and all of the hydrous oxides of iron save gothite, Fe_2O_3,H_2O.

In 2, the cleavage is expressed in accordance with the direction in which it is obtained as basal, if parallel with the base of a prism, as in topaz and the micas. Prismatic, if parallel with faces of a prism as in the amphibles which have two perfect prismatic cleavages. Cubical, if parallel with the faces of a cube as in galenite, PbS, and in halite, NaCl. Octahedral, if parallel with the faces of an octahedron as in fluorite, CaF_2, and the diamond, C. Dodecahedral, if parallel with the faces of rhombic dodecahedron as in sphalerite, ZnS, and in sodalite. Clinopinacoidal, if parallel with the face of the clinopinacoid as in gypsum.

Parting must be distinguished from cleavage for it is not due to a minimum cohesion simply but rather to a lamellar structure which is often connected with the presence of twinning laminae and sometimes to the action of secondary causes, as pressure. This parting is often observed in the pyroxenes and in titanite. In titanite the parting sometimes seems more perfect than the actual cleavage and the parting planes are often mistaken for the cleavage planes.

8—*Fracture.* The fracture of a mineral is the character of the broken surface other than that of cleavage or parting. The lines of fracture cross the cleavage planes at some angle Amorphous minerals are devoid of cleavage and therefore their broken surfaces represent fractures. The following fractures may be easily recognized.

(a) Even, when the mineral breaks with a fairly smooth surface. Example, the lithographic limestone of Estill and Meade Counties, Kentucky.

(b) Uneven, when the broken surfaces are more or less irregular. Example, tourmaline.

(c) Conchoidal, when the broken surfaces show concentric rings like a conch shell. Example, quartz, obsidian.

(d) Hackly, when the broken surfaces show many sharp and jagged points. Example, cyanite.

(e) Splintery, when the mineral breaks down into fine splinters or fibers. Example, pectolite.

(f) Earthy, when the mineral breaks down into a powder that is characteristic in appearance of soil grains. Example, bauxite, bentonite.

9—*Tenacity.* Tenacity is the property of a mineral that determines its toughness. Several different types of tenacity are recognized.

(a) Brittle, when the mineral is easily broken down into a powder. Example, pyrite, marcasite, pyrrhotite. Most ores of the useful metals are brittle.

(b) Sectile, capable of being cut with a knife. Example, silver.

(c) Malleable, capable of being hammered out into thin plates or sheets. Example, gold.

(d) Ductile, capable of being drawn out into a fine wire. Example, copper.

(e) Elastic, capable of being elongated and returning again to its normal form when the tension is relieved. Example, elaterite, the elastic bitumen of England.

(f) Flexible, capable of being bent and returning to its original position when the pressure is removed. Examples, muscovite, biotite, phlogopite.

10—*Diaphaneity.* Diaphaneity is the degree of transparency of a mineral. It refers to the degree of light transmitted through a mineral substance.

(a) Transparent, when objects are distinctly seen through a mineral. Examples, Iceland spar, muscovite.

(b) Subtransparent, when an object is seen through a mineral but its outline is indistinct. Example, some varieties of the amphiboles.

(c) Translucent. When no objects are seen but light is transmitted. Examples, anhydrite, Mexican onyx.

(d) Sub-translucent, when light is transmitted only through the thin edges of a mineral. Example, serpentine.

(e) Opaque, when the mineral transmits no light at all. Example, galenite. Most ores of the heavy metals are opaque.

11—*Taste.* Taste is the effect of some soluble constituent of a mineral upon special nerves in the mouth. All minerals soluble in water possess a characteristic taste which in certain cases leads to immediate identification.

(a) Saline, the taste of halite, or common salt.

(b) Bitter, the taste of epsomite. The most bitter mineral known.

(c) Acid. The taste of burning sulphur when the fumes are shaken up with water.

(d) Sweet, the taste of arsenolite, As_2O_3 is faintly sweetish.

(e) Astringent, the taste that produces a contraction as in the alums.

(f) Alkaline, the taste of the oxides of barium, strontium and calcium.

(g) Cooling, the taste of niter, KNO_3.

(h) Pungent, a sharp biting taste as in sal ammoniac, NH_4Cl.

(i) Metallic. A disagreeable, unpleasant taste as in decomposing sulphides of the heavy metals.

(j) Nauseating. The taste of chalcanthite, $CuSO_4.5H_2O$, or blue vitriol.

12—*Odor.* Odor is the effect of escaping constituents of a mineral upon the olfactory nerves. Some of these are best obtained by heat reactions, some by merely striking a mineral with a hammer, while others are obtained by moistening the mineral with water.

(a) Argillaceous. The odor obtained when clay is breathed upon or moistened with water. Example, kaolinite.

(b) Bituminous. The odor obtained when minerals containing bitumen are struck with a hammer. Example, asphalt.

(c) Fetid. The odor obtained when the specimen is struck with a hammer. Examples, barite, some sandstones, and some limestones.

(g) Garlic. The odor evolved when arsenic passes from the elemental state to that of the oxide. It is formed by stricking arsenopyrite with a hammer and by heating elemental arsenic or the compounds of arsenic on charcoal.

(e) Sulphurous. The odor of sulphur dioxid produced by roasting various sulphides of the metals on charcoal.

(f) Horse-radish. This is the very disagreeable and unmistakable odor formed when selenium passes from the elemental state into that of the oxide.

(g) Antimonial. This is the odor produced when metallic antimony passes from the elemental state into that of the oxide by roasting the native element on charcoal.

13—*Feel.* Feel is the effect of a mineral upon the sense of touch. Each metal and each mineral produces an effect that is characteristic.

(a) Cool. The feel of the precious and useful metals. The feel of a diamond. A gem may be thus distinguished from a paste.

(b) Greasy or unctuous. The feel of talc, sapolite and serpentine.

(c) Harsh. The feel of chalk and trachyte. White minerals like chalk and kaolinite may be easily distinguished by this test, for kaolinite when rubbed feels smooth and greasy while chalk under the same test is gritty.

(d) Smooth. The feel of a broken surface that is regular as in meerschaum.

14—*Adhesiveness.* Some minerals adhere strongly to the tongue when pressed upon it. Example, garnierite, the hydrous silicate of nickel and magnesium.

15—*Tarnish.* Certain minerals tarnish readily upon exposure to the atmosphere. Example, bismuth. This metal upon exposure assumes a reddish tinge while antimony remains untarnished.

16. *Iridescence.* Some minerals show a play of different colors as light strikes them at different angles. This is sometimes the result of some polarization phenomenon due to a lamellar structure as in the blue of labradorite. Iridescence may be caused by a thin coating or film of some other mineral on the surface as often seen in limonite.

17—*Opalescence.* Opalescence is seen in several minerals due to pearly reflections from the interior as on polished moonstone.

18—*Phosphorescence.* This power of emitting light is sometimes seen upon minerals after heating or after subjection to rays emanating from radium bromide as in willemite, Zn_2SiO_4.

CHAPTER IV.

CHEMICAL PROPERTIES

The chemical properties of minerals are those relating to the composition and the behavior of wet and dry reagents upon them. It involves the chemical changes that take place upon heating minerals in closed and open tubes, in the forceps, and upon charcoal.

Many minerals may be determined easily by their physical properties and modes of occurrence, but it is frequently advisable to employ fire reactions in their qualitative analysis. Chemical mineralogy is therefore qualitative mineral analysis and would correspond to qualitative analysis in chemistry. In mineralogy the following tests are usually applied.

1—*Heating minerals in closed tubes.* This work may be executed either in a closed tube or a matrass. A matrass is simply a closed tube with a bulb blown on the closed end. A closed tube is a piece of glass tubing closed at one end. A sealed tube is one closed at both ends. An open tube is one open at both ends so as to freely admit air through the tube.

The advantage of heating minerals in the closed tube is that they are heated out of contact with a current of air. If faint sublimates of the oxides of the metals occur they result from the presence of a small amount of oxygen within the tube. The reactions that take place may be listed as fusion, formation of sublimates in the upper part of the tube, escape of odors.

(a) Fusion. Few minerals fuse in the closed tube. Example, ceraragyrite, $AgCl$. Niter, KNO_3, melts but does not volatilize. Sulphur melts at a temperature varying from 115 to 119 degrees, and boils at 444.6 degrees. Several different colors are obtained in the fused and sublimed products.

(b) The formation of a sublimate in the upper part of the tube. These sublimates may be the mineral itself in which case the mineral vaporizes at a temperature below that which causes the dissociation of the mineral. Example, sal ammoniac, NH_4Cl. It may be a sublimate of sulphur alone as in pyrite,

FeS_2. It may be a sublimate of some sulphide as in prousite, $3Ag_2S,As_2S_3$, which yields a yellow sublimate of As_2S_3.

(c) The formation of odors. The odor of SO_2, that of a burning match, is obtained from the oxidation of the sulphur as it comes in contact with the air. The odor of garlic, or wild onions, is obtained when elemental arsenic is oxidized to As_2O_3. The odor of bitumen is obtained upon heating asphalt or cannel coal in the closed tube and the odor of organic matter is observed upon heating many samples of phosphate rock.

A few minor changes may also be noticed as follows:

(a) Change of color. Rhodochrosite, $MnCO_3$ which is normally a pink or rose color, becomes black due to the loss of carbon dioxide and the formation of an oxide of manganese. Zincite, ZnO, becomes a faint yellow when hot but is yellowish white when partly cold and white when cold.

(b) Phosphorescence. Several minerals when heated a little below redness phosphoresce in the dark. Fluorite, CaF_2, when heated to 150 degrees C. emits a purple or green light.

(c) Decrepitation. Many minerals when crystallized break down upon heating into smaller fragments due to unequal expansion or mechanically combined water. Galenite, PbS, and halite, NaCl, are examples.

2—*Heating in the open tube.* When minerals in the pulverulent form are heated in the open tube the conditions are favorable for their oxidation and oxides are formed of those metals that would yield sulphides in the closed tubes. The phenomena observed are fusion, formation of sublimate, escape of odors.

(a) Fusion. Niter, KNO_3, fuses but does not volatilize at moderately low temperatures.

(b) The formation of sublimates. In most cases these are oxides of the metals. Elemental arsenic volatilizes without fusion and the current of air sweeping through the tube oxidizes the gray metalloid to white As_2O_3 which is completely driven out of the tube by heating each sublimate of As_2O_3 formed within the tube. Minerals containing arsenic, like arsenopyrite, FeAsS, yield a white sublimate of As_2O_3. Stibnite, Sb_2S_3, a white sublimate of Sb_2O_3, but upon reheating the Sb_2O_3, a part of it is deposited further up on the walls of the tube and a part is oxidized to Sb_2O_5 which is non-volatile.

(c) The formation of gases which impart characteristic odors. Sulphur burns to SO_2 with the odor of a burning match. Arsenic oxidizes to As_2O_3 with a garlic odor. Antimony oxidizes to Sb_2O_3 with an antimonial odor. Selenium burns to SeO_2 with the odor of decomposing horse radish. Asphalt burns with the odor of burning oil.

3—*Heating the mineral in the forceps.* The forceps used may be either common steel, or platinum or nichrome tipped. The mineral is held in the apex of the non luminous cone which is the hottest part of the flame of a Bunsen burner. Two factors are observed, one the relative degree of fusion, and the other the color imparted to the flame.

(a) Degree of fusibility. Von Kobell has arranged a scale of fusibility which is in general use and which consists of 7 minerals arranged in the order of increasing resistance to fusion. It is here given for camparison.

1—*Stibnite.* Fusible in a candle flame in coarse splinters.

2—*Natrolite.* Fusible in a candle flame in fine splinters and in the flame of a Bunsen burner in coarse splinters.

3—*Garnet, var. Almandite.* Infusible in the candle flame but fusible before the blowpipe in medium splinters.

4—*Actinolite.* Fusible before the blowpipe only in fine splinters.

5—*Orthoclase.* Rounded on the thin edges with a fair amount of flame.

6—*Bronzite.* Rounded on the thin edges of very fine splinters only by prolonged heating.

7—*Quartz.* Infusible save in the highest heat of the oxy-hydrogen flame.

(b) Colors imparted to the flame. This is often a positive guide in the detection of certain bases. Compounds of barium give a green to yellowish flame.

Compounds of strontium and lithium a crimson color.

Compounds of calcium give a yellowish red to a brick red coloration.

Compounds of sodium impart an intense, persistent yellow to the flame.

Compounds of potassium impart a pale violet color best seen through a small piece of blue glass. The common sodium rays are absorbed and the potassium ray is transmitted thru the glass.

Many compounds of copper impart a green to emerald green color to the flame but copper chloride gives a beautiful azure blue.

Sulphur and carbon with a blue flame.

Arsenic burns with a livid blue flame.

Metallic zinc burns with a bluish green flame.

4—*Heating on charcoal.* Sticks of charcoal are obtained by burning pieces of wood about four inches by one inch by one inch until thoroughly charred. The stick may be made from alder, basswood, beech, pine or willow. In using the charcoal it is best to cut or bore out with a charcoal borer a hole in which fragments of the mineral are placed before heating.

A—*Fusion without flux.* Minerals that fuse readily without a flux are treated alone on the charcoal. Several important things should be noticed.

(a) Fusion. Most of the precious and useful metals fuse readily to a metallic button. Lead, Pb, melts at 327 degrees and forms a soft lead-gray button on the coal. Gold, Au, fuses at 1065 degrees to a golden yellow button, greenish while intensely hot.

(b) The formation of sublimates on the coal. Most of the useful metals form sublimates on the coal. Lead forms a buff sublimate. Arsenic a white sublimate. Zinc a sublimate that is yellow when hot and white when perfectly cold.

(c) The chasability of the sublimates. The sublimate of lead oxide, PbO, can be driven around over the coal and reduced back to globules of metallic lead. The sublimate of antimony oxide, Sb_2O_3, is driven from the coal but not reduced. The sublimate of tin oxides, SnO_2, cannot be driven from the coal.

(d) Magnetism. The iron, cobalt and nickel minerals with volatile acid radicles reduce to metallic grains or buttons that are magnetic. Ores of copper, like chalcopyrite, $CuFeS_2$, reduce readily to metallic, magnetic buttons but the magnetism is due only to the iron in the minerals.

(e) Odors. Sulphur and the sulphides of the metals when heated evolve the odor of SO_2, the burning match. Elemental arsenic and ores containing arsenic evolve the garlic odor. Selenium and compounds containing it evolve the odor of decomposing horse-radish.

B—*Heating with* Na_2CO_3. The sodium carbonate serves as a flux. Most minerals that are infusible alone on the charcoal fuse readily in the presence of Na_2CO_3. Example, quartz, SiO_2.

(a) Sublimates without reduced metal.

1—Arsenical compounds give a white volatile sublimate and emit a strong garlic odor.

2—Selenium gives a steel gray sublimate and emits the strong odor of decomposing horse-radish.

3—Cadmium gives a reddish-brown to orange colored sublimate often showing a beautiful iridescence. The sublimate is volatile.

4—Zinc compounds yield a sublimate that is yellowish-white when partly cooled and white when cold. It cannot be driven around over the coal.

5—Tellurium gives a white sublimate, often with a reddish or dark yellow border. It can be volatilized.

(b) *Reduced metal with sublimate.*

1—Lead compounds yield a buff coating, PbO, on charcoal and a gray metallic button. The sublimate is chasable and reducible.

2—Bismuth gives an orange-yellow sublimate of Bi_2O_3 which is volatile but does not reduce to metallic bismuth. The button of metallic bismuth is malleable when warm but brittle when cold.

3—Antimony yields a dense white coating of Sb_2O_3 near the assay and a gray to tin white brittle button. This button when heated intermittently continues to vaporize forming acicular crystals of artificial valentinite, Sb_2O_3.

4—Metallic tin gives a coating near the assay, yellow when hot and white when cold. The sublimate cannot be driven about over the coal. The button is silver white and somewhat malleable.

(c) *Reduced metal without any sublimate.*

1—Silver compounds reduce to silver-white, soft, ductile, malleable buttons. The silver may be confirmed by dissolving the button in HNO_3 and adding hydrochloric acid, HCl, a white curdy precipitate of AgCl is formed which is soluble in NH_4OH.

2—Copper compounds reduce to a copper red malleable button which when moistened with hydrochloric acid imparts a bluish green to azure blue coloration to the flame. The button is soluble in HCl and upon the addition of ammonium hydroxide, NH_4OH, a deep indigo blue solution is formed.

3—Gold, and the compounds of gold, yield a golden yellow malleable button which is soluble in aqua regia. The solution evaporated nearly to dryness and diluted with water gives with stannous chloride in the presence of stannic chloride of free chlorine, a finely divided precipitate which renders the solution purple in color, known as the Purple of Cassius.

4—Iron compounds reduce to magnetic particles or buttons. The high degree of magnetism distinguishes these particles from all other metals. With a nitric acid solution of the metal potassium ferrocyanide gives a dark blue precipitate.

5—Small particles of reduced cobalt when fused with borax in the loop of a platinum wire, or on charcoal, impart a smalt blue color to the bead. This coloration is obtained in both the oxidizing and the reducing flames.

6—Small particles of reduced nickel when dissolved in HNO_3 and sodium hydroxide, $NaOH$, is added yield an apple green precipitate of $Ni(OH)_2$.

C—*Heating with Metallic Sodium or Potassium.* Metallic sodium is generally used because it is cheaper. A few minerals fuse only with difficulty on prolonged blowing with sodium carbonate but fuse easily when pulverized, rolled up in a piece of metallic sodium and treated on charcoal.

1—Casserite, SnO_2, reduces to metallic tin which quickly oxidizes to SnO_2 and is deposited as a sublimate, yellow when hot, that cannot be driven around over the coal. This sublimate moistened with the nitrate of cobalt and reheated becomes bluish green in color.

2—Zincite, ZnO, reduces and readily oxidizes to ZnO which cannot be driven around over the coal. It is yellow when hot and white when cold. If moistened with nitrate of cobalt and reheated the sublimate becomes green in color and is known as Rinmann's green.

D—*Fusion with borax.* Corundum, Al_2O_3, is infusible with sodium carbonate. When pulverized and mixed with four parts of borax to one part of the mineral the product fuses on charcoal and is rendered soluble in mineral acids. When NH_4OH is added to a HCl solution a white gelatinous precipitate of $Al_2(OH)_6$ is formed.

E—*Fusion with Bismuth Flux.* The use of the mixture known as bismuth flux is practically confined to reactions involving salts of bismuth and lead. With bismuth the flux gives a yellowish white sublimate with a bright crimson border. The crimson color is due to the formation of bismuth tri-iodide, BiI_3. With lead compounds and bismuth flux a yellowish green film is obtained on the coal. The flux consists of two parts sulphur, one part of potassium iodide and one part of acid potassium sulphate.

F—*Fusion on Plaster Tablet.* These tablets are easily made, practically inexpensive, and with their smooth white surface upon which colored sublimate may be formed, they are in common use in blowpipe work. A small depression is cut out with a knife, or the end of a file, so as to hold the assay on the tablet.

The oxidizing flame is generally used. In some cases the metal itself is volatilized and in others an oxide of the metal is formed which is deposited upon the cold surface of the tablet. Sublimates are obtained by treating the mineral alone on the tablet or identified by the use of bismuth flux. Cobalt nitrate, hydrobromic acid or yellow ammonium sulphide.

1—Cadmium yields a reddish brown to brownish black sublimate which is often iridescent. The sublimate is the oxide, CdO. The carbonate of cadmium which compound is associated with smithsonite, the carbonate of zinc, yields carbon dioxide and the assay itself becomes reddish brown. The reduced metal quickly volatilizes and gives the characteristic cadmium coating on the tablet.

2—Carbon is obtained as a brownish black, non-volatile sublimate by heating Kentucky rock asphalt or other carbonaceous mineralloids on the tablet.

3—Metallic arsenic gives a black sublimate of the metalloid which is overlaid by a white coat of the oxide, As_2O_3. The sublimate is entirely volatile.

4—The sulphides of arsenic give a yellowish to reddish brown coat which when the assay is too rapidly heated become brownish black.

5—Mercury, by cautiously heating, yields a drab gray, extremely volatile sublimate.

6—Elemental selenium, which is a metalloid, affords a sublimate of the element which is crimson in thin layers, otherwise cherry red. The characteristic odor of decomposing horse-radish is always observed as the assay passes from selenium into the oxide, SeO_2.

7—Metallic tellurium yields a volatile coating which is brown to black in color and often tinged with blue near the assay. When this coating is moistened with conc. H_2SO_4 and gently heated a beautiful pink tellurium sulphate is observed.

G—*Reactions with $HKSO_4$.* Acid potassium sulphate is a common and valuable fluxing agent. It renders many insoluble minerals when fused with the flux on charcoal, readily soluble in mineral acids. When the pulverized minerals are fused with $HKSO_4$ in a matrass certain gasses are evolved that easily identify the acid radicle in the mineral.

1—Acetates give a colorless gas with the odor of acetic acid or vinegar.

2—Bromides yield a heavy brown vapor due to the liberation of bromine, with a pungent odor.

3—Chlorates give a yellowish green vapor due to the liberation of ClO_2. The odor of chlorine, Cl, is very irritating.

4—Chlorides yield HCl vapor which is colorless and forms dense white clouds of ammonium chloride, NH_4Cl, when the escaping gas comes in contact with NH_4OH.

5—Carbonates evolve a colorless gas, CO_2, which if passed into lime water held in the loop of a platinum wire turns it turbid.

6—Fluorides evolve the corrosive gas HF, hydrofluoric acid, which etches the glass above the assay.

7—Iodides yield dense violet vapors which are accompanied with particles of free iodine that form a metallic sublimate in the tube.

8—Nitrates and nitrites afford a reddish brown pungent gas which is NO_3.

9—Oxalates afford first colorless carbon monoxide, CO, which burns with a blue flame.

10—Sulphites evolve the colorless, suffocating gas, SO_2, which has the odor of a burning match.

11—Sulphides yield hydrogen sulphide, H_2S, which has the characteristic odor of decomposing eggs. The gas turns black a piece of filter paper moistened with silver nitrate.

II—*Microcosmic Salt*, $NaH(NH_4)PO_4.4H_2O$. This salt is often used as flux to remove volatile acid radicles and to obtain characteristic colored beads in a similar manner as borax is used.

The microcosmic beads in the reducing flame for the common metals are as follows:—

Copper, blue when hot and red when cold. Iron, red to yellow when hot and brown when cold. Chromium, red when hot and green when cold. Cobalt, blue both when hot and cold. Nickel, red when hot and yellow when cold. Manganese, in small quantities colorless both when hot and when cold.

DRY REAGENTS

Several dry reagents are valuable aids in the identification of minerals. These reagents are best stored in wide-mouthed glass bottles.

1—Bismuth flux. This flux consists of a mixture of two parts of sulphur, one part of potassium iodide and one part of acid potassium sulphate. It is used in the detection of bismuth and lead.

2—Boracic acid flux. This flux consists of three parts of acid potassium sulphate, $HKSO_4$, and one part of powdered fluorite, CaF_2. When boron bearing minerals are fused with four parts of this mixture and one part of the powdered mineral the water is first expelled and then fluo-boracic acid is formed which imparts an apple green coloration to the flame.

3—Borax, $Na_2B_4O_7$, 10 H_2O. This material is constantly used in securing colored beads of the useful and rare metals, a skeleton of silica from the fusion of the varieties of quartz and the silicates, and in the fusion of such aluminum minerals as corundum, ruby, sapphire and emery.

4—Borax glass. This flux consists of borax which has been fused and pulverized. It is used largely in assaying and is sometimes substituted for commercial borax in blowpiping.

5—Charcoal. Many minerals are fused on charcoal and reduced to the metal or metals contained in them. It serves therefore as a reducing agent. If pulverized charcoal is placed in a closed tube above some arsenic mineral as arsenolite, As_2,O_3, the charcoal heated to redness, then the mineral heated, a mirror of metallic arsenic is formed within the tube.

6—Mossy tin and zinc. The metals are melted and poured into cold water. The sudden chill coarsely subdivides the metal. They are often fused on charcoal with the powdered mineral to be tested or a borax bead made from the mineral to remove some interfering element and permit the identification of the metal sought, as in wolframite, $FeMnWO_4$. They are used in acid solutions of the metals as a reducing agent.

7—Microcosmic salt $HNaNH_4PO_4$, $4H_2O$. This salt may be used as a fluxing agent in identification of colored beads and in the liberation of certain acid radicles. In heating water and ammonia they are expelled and sodium metaphosphate is formed.

8—Potassium bisulphate, $HKSO_4$. This reagent is used as a flux and in the liberation of certain corrosive gases, as HF from treatment of fluorite, CaF_2.

9—Potassium iodide, KI. This reagent is especially valuable in the identification of a sublimate supposed to contain bismuth. When a few crystals of KI are fused with a sublimate of Bi_2O_3 a beautiful crimson product of BiI_3 is formed. In case of lead a yellow lead iodide, PbI_2 is formed.

10—Potassium nitrate. This salt is used as an oxidizing agent in the presence of fluxing mixtures.

11—Ribbon of magnesium. This metal is used in the detection of phosphoric acid. Powdered phosphate mixed with pieces of magnesium ribbon, fused on charcoal and moistened with water emit the offensive odor of phosphine, PH_3.

12—Silver coin. The coin is used in the detection of sulphur in all sulphides and sulphates. The mineral is fused on charcoal with sodium carbonate, transferred to a silver coin, moistened with water and allowed to stand a few minutes. If sulphur is present a brownish black to black stain appears on the coin due to the formation of silver sulphide, Ag_2S.

13—Sodium carbonate, Na_2CO_3, or sodium bicarbonate, $NaHCO_3$, is used. The carbonate is used as a fluxing agent in decomposing minerals, reducing metallic minerals on charcoal and in the hepar test for sulphur.

14—Test papers. Red litmus paper is used to identify alkaline solutions. Blue litmus to identify acid solutions. Turmeric paper is the identification of boracic acid, and compounds of zirconium and titanium.

15—Copper oxide, CuO. The black oxide of copper is used to identify chlorine in chlorides. A few grains of halite, NaCl, mixed with copper oxide and fused in the Bunsen flame impart an intense bluish green coloration to the flame.

16—Sodium, Na. Metallic sodium is used in reduction to the elemental state of easily fused ores like AgCl, and infusible minerals like casiterite, SnO_2.

WET REAGENTS

Wet or liquid reagents are constantly used in qualitative mineral analysis for confirmatory tests. The number used in a given laboratory may be very small or for a more thorough investigation a considerable number may be employed.

1—Acids. Hydrochloric acid, HCl. This acid may be used in the concentrated form or diluted with two parts of water. It liberates hydrogen from certain metals, hydrogen sulphide from the sulphides of most metals, carbon dioxide from all carbonates, chlorine from all oxides and hydrous oxides of manganese above MnO.

2—Nitric acid, HNO_3. This acid in either the concentrated form or diluted with 2 parts of water is used as a solvent for sulphides, and to oxide ferrous iron to ferric iron.

3—Sulphuric acid, H_2SO_4. This acid is used to decompose certain silicates and to precipitate barium, strontium, calcium and lead from their various solutions.

4—Alcohol, C_2H_5OH. Ethyl alcohol is used in the detection of boric acid in the borates. After their sulphuric acid solution has been evaporated nearly to dryness, alcohol added and ignited, a green flame is obtained.

5—Ammonium carbonate. $(NH_4)_2CO_3$. This reagent is used to precipitate from their solutions barium, strontium, and calcium as carbonates.

6—Ammonium chloride, NH_4Cl. This reagent is used to prevent the precipitation of magnesium by ammonium hydroxide, that it may be precipitated after adding ammonium carbonate by disodic phosphate.

7—Ammonium hydroxide, NH_4OH. One part of C. P. ammonia may be diluted with an equal volume of water. The reagent is used to throw out of solution as hydrates, iron, aluminum, and chronium and to render solutions alkaline.

8—Ammonium molybdate, $(NH_4)_2MoO_4$. This reagent is used in the detection of phosphoric acid. Precipitation is best obtained at a temperature of about 84 degrees when a yellow crystalline precipitate of ammonium phosphomolybdate is formed.

9—Ammonium oxalate $(NH_4)_2C_2O_4$. This solution is used to precipitate calcium from its solutions.

10—Ammonium sulphide $(NH_4)_2S$. This reagent formed by passing H_2S gas into C. P. ammonia should be yellow in color. It is used to precipitate cobalt, nickel, manganese and zinc from alkaline solutions.

11—Aqua regia, three parts of HCl to one part of HNO_3 is used to dissolve gold and platinum.

12—Barium chloride, $BaCl_2$ is used to detect sulphuric acid in all soluble sulphates by giving a white precipitate of barium sulphate.

13—Calcium hydroxide, $Ca(OH)_2$. Lime water is made by dissolving lime, CaO, in water and decanting the clear liquid. It is used in the detection of carbon dioxide.

14—Cobalt nitrate, $Co(NO_3)_2$, this solution is used in testing strongly ignited minerals and certain sublimates. When a drop of cobalt nitrate is added to a piece of mineral which has been strongly heated, and the assay is heated again strongly, aluminum compounds impart a deep blue coloration. With magnesium compounds it gives a pink coloration, with a sublimate of dioxide of tin it affords a bluish green coloration, and with the oxide of zinc a green coloration.

15—Dimethylgloxime, $C_4H_8O_2N_2$, is used to precipitate nickel from an alkaline solution as a red precipitate. Dilute alcohol 50 per cent, add a little ammonium hydroxide and make a saturated solution of the salt before using.

16—Disodic phosphate. Na_2HPO_4. A solution of this reagent is used to precipitate magnesium from its alkaline solutions after the removal of all preceding groups. The white crystalline precipitate is magnesium ammonium phosphate, Mg,NH_4,PO_4. Microcosmic, salt (Dry reagents, 7,) answers the same purpose.

17—Ferrous sulphate, $FeSO_47H_2O$. A solution of ferrous sulphate is used in the identification of nitrates. When an aqueous solution of a nitrate is treated with ferrous sulphate either as a solid or as solution and conc. H_2SO_4 is slowly poured into the solution, a brown ring is formed at the junction of the two liquids.

18—Hydrogen peroxide, H_2O_2. This reagent is used in the detection of vanadium. Dissolve a vanadium mineral in conc. HCl, dilute with H_2O, add H_2O_2, the color obtained is red or reddish brown.

19—Potassium ferrocyanide, $K_4Fe(CN)_6$, is used to detect ferric iron.

20—Potassium ferricyanide, $K_3Fe(CN)_6$, is used to detect ferrous iron. The precipitate is Prussian blue in color. It also precipitates a red uranium ferrocyanide.

21—Potassium hydroxide, KOH, either the solid sticks or aqueous solution may be used to liberate ammonia from its various compounds.

22—Silver nitrate, $AgNO_3$. This solution is used to detect the presence of chlorine in all chlorides. A little HNO_3 gives a white curdy precipitate of AgCl.

23—Sodium hydroxide, NaOH, either in solid form or aqueous solution may be used to liberate ammonia from its various compounds. It is also used to precipitate nickel from solutions free from ammonia as an apple green nickel hydroxide, $Ni(OH)_2$.

24—Stannous chloride, $SnCl_2$, in the presence of stannic chloride, $SnCl_4$, or free chlorine, is used to detect the presence of gold. With these reagents and a dilute solution of the trichloride of gold, $AuCl_3$, Purple of Cassius is formed.

Calcite-Dolomite Tests

The limestone and marbles of Kentucky are in part calcitic, in part dolomitic, and in part pure dolomites. It therefore seems advisable to give here a few simple tests whereby these different types of minerals may be distinguished.

1—Pulverized calcite effervesces freely in cold, dilute HCl. Under the same condition dolomite effervesces feebly, due to occluded molecules of calcite. Magnesite, $MgCO_3$, similarly treated should suffer no immediate change.

2—Calcite when treated with a solution of aluminum chloride, $AlCl_3$, and haematoxylin (extract of logwood) receives a violet coating. Dolomite, under the same conditions, remains uncolored.

3—Pulverize a few grains of the calcareous rock, cover with water and add a few drops of phenolphthalein solution. Calcite gives a strong coloration. Dolomite is but slightly tinted, if tinted at all.

CALCITE-ARAGONITE TESTS

As fibrous and sometimes radiating calcite is often mistaken for aragonite a few simple tests are here given whereby calcite may be distinguished from aragonite.

1—Before the blowpipe calcite is infusible, loses carbon dioxide, becomes alkaline, glows, and colors the flame yellowish red or brick red. Aragonite, under the same condition, loses carbon dioxide, whitens, falls to pieces, and colors the flame a brick red.

2—Calcite with a solution of ferrous sulphate in the presence of air gives a yellow precipitate. Aragonite under the same treatment gives a dark green precipitate.

3—Calcite with congo red affords no coloration while aragonite becomes pink and sometimes spotted.

4—Calcite with silver nitrate and potassium bichromate affords no coloration while aragonite becomes red.

5—Calcite with a solution of cobalt nitrate remains uncolored in the cold but becomes bluish upon boiling. Aragonite under the same treatment gives a lilac color which becomes intensified by boiling.

CHAPTER V.

USEFUL BLOWPIPE TESTS

As a matter of convenience the elements listed in this chapter are arranged in alphabetical order. The details of manipulation are omitted because largely given elsewhere in preceding chapters and only the results stated. The bead tests are usually obtained with the oxides. Many minerals are converted into the oxide by roasting.

ALUMINUM, Al

Most aluminum compounds, when treated with sodium carbonate swell up and form an infusible compound. When the roasted assay is moistened with the nitrate of cobalt, $CO(NO_3)_2$, a blue coloration is obtained. When NH_4OH is added to a solution of an aluminum mineral other than phosphate a white gelatinous precipitate of $Al_2(OH)_6$ is obtained. The borax and salt of phosphorus beads are clear or cloudy. To an HCl solution add an equal volume of ether, pass HCl gas through the solution until the diversion between the layers of the two liquids disappears. $AlCl_3$ precipitates as white crystalline substance, $AlCl_3$, $6H_2O$. Be fails to crystallize.

AMMONIUM, NH_4

When ammonium minerals are heated in a matrass or closed tube with NaOH, or KOH, or CaO, the gas NH_3 is liberated. This is recognized by the odor of household ammonia. If the escaping vapor is held near an unstoppered bottle of conc. HCl dense white fumes of NH_4Cl are formed.

ANTIMONY, Sb

When antimony is heated on charcoal with the reducing flame a volatile white coat of Sb_2O_3 is formed on the coal. The button of molten antimony dropped on paper continues to vaporize charring the paper where the button momentarily rested and connecting each dark spot with a thin coating of the white oxide. In the closed tube the oxide will yield a white sublimate of acicular crystals of Sb_2O_3. In the open tube a dense white amorphous sublimate. If sulphur is present a sublimate red in spots may be obtained. With bismuth flux on a plaster tablet a somewhat mottled, peach red coat is obtained which when moistened with a drop of $(NH_4)_2S$ produces an orange red ring of Sb_2S_3. The flame of antimony is a pale yellowish green.

INTERFERENCES

Arsenic, copper, lead and bismuth are interfering elements. Elemental As should be removed by gently heating the assay on coal. If the arsenic is combined with S as in realgar, As_2S_2 by heating gently in a closed tube. The S.Ph bead with tin may be momentarily red but will soon blacken If lead and bismuth are present the assay should be heated intermittently.

ARSENIC. As

It is often of advantage to coat a plaster tablet with soot from a burner before fusing As. The white coat of octahedral crystals of As_2O_3 is then better observed. A very volatile white coat is formed on charcoal. As arsenic passes from the elemental state to arsenous oxide, As_2O_3, the strong garlic odor is obtained. With bismuth flux on a plaster tablet the coating is orange red and on coal a faint yellow. The flame of burning As is a pale azure blue. Elemental arsenic and the arsenides when heated in a closed tube give a metallic mirror. In the open tube elemental arsenic, the arsenides and the sulphides yield a white, completely volatile sublimate of octahedral crystals of As_2O_3.

INTERFERENCES

Antimony, cobalt, nickel and sulphur are interfering elements. To prove that the mirror in the closed tube is As treat the product on charcoal for the garlic odor. If cobalt or nickel are suspected to be present fuse the product with lead and note the garlic odor. A red to yellow sublimate is obtained when the sulphides of arsenic are heated in the C. T. These sublimates should be fused with soda on charcoal to obtain the garlic odor.

Barium, Ba

Barium minerals when fused with sodium carbonate sink into the coal. When moistened with mineral acid their flame is yellowish green. Their beads are clear and colorless but can be rendered opaque by flaming. From their solutions barium is precipitated by H_2SO_4 as white heavy barium sulphate, $BaSO_4$.

Beryllium, Be

Beryllium is precipitated as a hydrate by NH_4OH and in this respect resembles Al. With ammonium carbonate it is precipitated as a white precipitate of beryllium carbonate which is soluble in excess of the reagent. Solutions af aluminum compounds are not precipitated as carbonates. Acid sodium carbonate precipitates beryllium from nearly neutral solutions as a carbonate which is soluble in excess of the reagent.

Bismuth, Bi

Metallic bismuth on coal forms a volatile sublimate which is a dark orange yellow when hot and lemon yellow when cold. It often shows a yellowish white border. By fusing this sublimate with crystals of KI a bright scarlet product BiI_3 is formed. By fusion with bismuth flux on a plaster tablet a bright scarlet sublimate is obtained. This may be surrounded by a chocolate brown coat or even a reddish border. The brown coat may be made red by adding a few drops of NH_4OH. With bismuth flux on coal a bright red coat is obtained which may have an inner fringe of yellow. When treated with S.Ph in O. F. and granulated Sn in the R. F. is colorless when hot but blackish gray when cold. The reduced metal is somewhat malleable when hot but is brittle when cold. Therefore reduced buttons should be thoroughly cooled before testing their brittleness.

Interferences

Antimony and lead are the two interfering metals. In case Sb is present the coat is fused with boracic acid and then treated on a plaster tablet with bismuth flux. In case Pb is present the sublimate is best dissolved in S.Ph and in O. F. and reduced with Sn in the R. F.

BORON, B

All borates intermesce and fuse on charcoal. The flame is yellowish green in color. The color is intensified by moistening the mineral with H_2SO_4. It may also be obtained by making a paste of the mineral with H_2SO_4 and ammonium fluoride, NH_4F. It is best obtained by mixing four parts of acid potassium sulphate, $HKSO_4$ one part of powdered fluorite, CaF_2 and one part of the mineral to be tested. After the water has been expelled, then fluo-boracic acid is evolved which imparts an apple green coloration to the flame.

BROMINE, Br

All bromides yield a brown irritating vapor when fused in a matrass with $HKSO_4$. When a bead is made of the mineral, copper oxide and S.Ph and treated at the tip of the blue flame, the bead will be surrounded by blue and green flames. All HNO_3 solutions of bromides give a yellowish white precipitate of AgBr when $AgNO_3$ is added.

CADMIUM, Cd

The sublimates from cadmium are best obtained from the metal itself, but cadmium is not known to occur free and uncombined in nature. Cadmium compounds yield on charcoal in the R. F. a dark brown sublimate of CdO which in thin layers is greenish yellow. The sublimate is often iridescent. It is easily volatilized from the coal.

The sublimate is more easily recognized by using a plaster tablet in place of the coal. If the mineral is mixed with bismuth flux and fused on the tablet a white sublimate is obtained which becomes yellow on adding $(NH_4)_2S$.

INTERFERENCES

Lead, bismuth and zinc may be eliminated by mixing the sublimate with pulverized charcoal and heating gently in a closed tube. Either a metallic mirror or a reddish brown ring will be obtained if cadmium is present.

CALCIUM, Ca

Calcium minerals, unlike barium and strontium, do not sink into the coal when fused with soda. The flame is yellowish red to brick red intensified by moistening with HCl. The S.Ph bead is clear and colorless and can be flamed opaque. Calcium is precipitated from its alkaline solutions by ammonium oxalate as a white crystalline precipitate of calcium oxalate, CaC_2O_4.

CARBON, C

Carbon will burn in a platinum spoon in a jar of oxygen to carbon monoxide which burns with a blue flame to carbon dioxide.

The hydrocarbons and oxygenated hydrocarbons upon heating in closed tubes afford oily and tarry products which burn with a luminous and sooty flame. The residue in the tube is largely carbon.

CARBON DIOXIDE, CO_2

All carbonates effervesce when in the pulverulent state, they are treated with warm dilute HCl. If lead carbonate, $PbCO_3$ is the mineral treated then white crystals of $PbCl_2$ will form as the solution cools. Calcite and aragonite effervesce freely in cold dilute HCl. The escaping gas from all carbonates is CO_2 which turns turbid a drop of lime water when held in the loop of a platinum wire.

If a clear bead has been made of either borax or S.Ph and a carbonate added there will be effervescence upon further fusion.

CHLORINE, Cl

If a paste is made of the mineral, copper oxide and a drop of H_2SO_4, then dried gently in the O. F. and treated with the blue flame, the flame will first be colored greenish blue and then azure blue. If a mixture is made of the chloride, copper oxide and S.Ph and held at the tip of the blue flame an intense azure blue coloration is obtained.

All chlorides are precipitated from their HNO_3 solutions by a few drops of $AgNO_3$ as a white curdy precipitate of $AgCl$, soluble in NH_4OH.

Chromium, Cr

The bead tests for chromium minerals afford colors that are red to yellow when hot and emerald green when cold. Mixed with soda and treated on the coal the assay in the O. F. is a dark yellow when hot and a light yellow when cold. In the R. F. it is opaque and yellowish green when cold. If the mineral is fused with $HKSO_4$ in C. T. the assay is a dark violet when hot and greenish when cold. If lead nitrate is added to an acid solution of a chromate a yellow precipitate of $PbCrO_4$ is formed. To a solution of a chromate add one or two cc of ether, then add H_2O. The ether layer becomes blue.

Interferences

If manganese is present the soda beads will be a bright yellowish green. To a solution of a chromate in HNO_3 (1:9) add two cc of ether and one cc of 3% H_2O_2 and shake. A blue coloration of the ether layer proves the presence of chromium. This blue color is due to one of the perchromic acids, H_3CrO_7. It is unstable and decomposed by excess of H_2O_2, by too weak acid, or by raising the temperature. The reaction is very delicate and 0.2 milligram of chromium can be detected by this method.

Cobalt, Co

Cobalt compounds are very easy to identify for they impart a blue color to both the borax and the S.Ph beads in both the O. F. and R. F. Metallic cobalt is magnetic and retains its magnetism at a high heat unlike iron and nickel.

Interferences

Arsenic, sulphur and selenium are the interfering elements. The ores should therefore be carefully roasted to liberate each of these volatile constituents before attempting to make a borax bead, even on charcoal. Minerals like smaltite, $CoAs_2$, rapidly dissolve a Pt wire.

COLUMBIUM, Cb

Fuse the mineral on charcoal with $HKSO_4$, crush, dissolve in conc. HCl, add granulated Sn. The solution is blue and remains blue on moderate dilution. Tantalum under same treatment rapidly loses its blue color while tungsten retains its color.

COPPER, Cu

Copper compounds reduce readily to a red malleable button on coal. The oxides of copper color the flame emerald green but when the oxides are moistened with HCl, or aqua regia, the flame is azure blue. The blue coloration is also obtained by saturating a S.Ph bead with the mineral and adding NaCl. The borax bead in the O. F. is green when hot and greenish blue when cold. In the R. F. it is greenish or colorless when hot and brownish red when cold. HH_4OH added to the various solutions of copper produce a deep indigo blue coloration.

INTERFERENCES

Sulphides of copper and compounds containing As or Sb should be thoroughly roasted on charcoal before making the bead test.

FLUORINE, F.

If a fluorine bearing mineral is fused with $HKSO_4$ in a matrass HF is evolved which etches the glass. If S.Ph is used HF is also liberated. If silica is present then a ring of silica may be seen in the upper part of the tube. If heated with conc. H_2SO_4 and pulverized quartz and the escaping gas condensed by a drop of water in the loop of a Pt wire, a film of silicic acid will form on the water.

GOLD, Au

Metallic gold readily forms a golden yellow malleable button on coal provided the precious metal is present in sufficient amount to collect. The selenides and tellurides reduce to metallic gold. The tri-chloride of gold formed by dissolving gold in aqua regia gives, in the presence of $SnCl_2$ or free chlorine, a finely divided precipitate known as the Purple of Cassius. Upon intense and continued heating of gold on a plaster tablet a slight sublimate, rose to purple colored, may be seen near the assay.

HYDROGEN, H

Minerals containing hygroscopic moisture, water of crystallization, or chemically combined water, when pulverized and heated in C. T. or O. T. evolved water which is condensed in drops upon the walls of the tube. The water evolved is sometimes neutral, sometimes acid, sometimes alkaline.

IODINE, I

All iodides when heated with $HKSO_4$ in C. T. liberate a violet irritating vapor and give a brown sublimate of iodine. In the O. T. with two parts S and one part Bi_2O_3 a brick red sublimate is obtained. With the same flux on charcoal a scarlet coat is obtained. When heated cautiously with conc. H_2SO_4 and starch a blue to purple coloration appears which is due to the formation of the blue iodide of starch.

IRON, Fe

Native iron, magnetite, troilite, pyrrhotite and franklinite are magnetic before heating. The sulphides and arsenides of iron become magnetic upon roasting alone. Soda is an aid in roasting other iron compounds. With borax in the O. F. the bead is red to yellow when hot and yellow to colorless when cold. In the R. F. the head is bottle green. With S.Ph in the O. F. the bead is red to yellow when hot and yellow to colorless when cold. In the R. F. the bead is red both when hot and cold but greenish while cooling. If a blue borax bead is made of CuO this bead is rendered red by ferrous iron and greenish by ferric iron.

INTERFERENCES

Sulphur and arsenic may be removed by roasting. Copper may be removed from borax by fusion with lead on coal in R.

F. Cobalt beads may be diluted with borax until the blue color disappears. Nickel may be faded from borax in R. F. Manganese colors may be washed out by treatment with tin. Chromium may be removed by fusing the mineral with Na_2CO_3 and $NaNO_3$ on Pt foil dissolving the mass and testing residue for Fe. If either W or Ti is present the S.Ph bead will be reddish brown rather than blue or violet. $K_4Fe(CN)_6$ added to an acid solution containing iron gives a Prussian blue coloration. KCNS gives a yellow colored solution of $Fe(CNS)_3$.

LEAD, Pb

Lead minerals can be reduced in either the O. F. or the R. F. to soft, malleable lead gray buttons of metallic lead. In the O. F. this button yields near the assay a dark yellow coat surrounded by a buff sublimate which in turn is bordered by a bluish white coat in thin layers. The coat is volatile and reducible. A chrome yellow coat which is turned black by $(NH_4)_2S$ is obtained with bismuth flux on a plaster tablet. With lead minerals an azure blue flame can be secured. If a lead mineral is pulverized, a few drops of HNO_3 and a few crystals of KI are added a deep yellow precipitate of PbI_2 is formed. The sulphides of lead are dissolved in conc. HNO_3 with a separation of spongy porous sulphur which upon boiling is completely oxidized to white, insoluble lead sulphate, $PbSO_4$.

INTERFERENCES

Arsenic should be removed by gently roasting the assay in the O. F. Cadmium by roasting in the R. F. Antimony by fusion on coal with boracic acid and then on a plaster tablet. The bismuth flux test on plaster is usually sufficient.

LITHIUM, Li

Lithium bearing minerals impart a carmine red coloration to the flame. It is intensified by HCl. The color is less persistent than the crimson of strontium. If a few drops of barium chloride are added to the material to be tested the carmine red of lithium is seen before the green of barium appears. The crimson flame of strontium will appear after the green of barium.

INTERFERENCES

If there is doubt between the carmine red of lithium and the crimson of strontium a green glass may be used. The lithium ray is transmitted through the glass and the strontium ray is absorbed. If silica is present the powdered mineral should be made into a paste with boracic acid and water and tested in the blue flame. The carmine red lithium color appears after the flux has fused.

MAGNESIUM, Mg

Magnesium minerals treated with soda on the coal are insoluble and the fused product does not sink into the coal. When treated with borax or S.Ph a clear and colorless bead which can be flamed opaque white is obtained. With the nitrate of cobalt on charcoal the product becomes pink. Metallic magnesium burns with a dazzling white light. Magnesium is precipitated from its alkaline solutions by Na_2HPO_4 as a white crystalline magnesium ammonium sulphate.

MANGANESE, Mn

Manganese is one of the easiest bases to identify. With borax or the S.Ph in the O. F. manganese minerals give an amethystine bead which in the R. F. becomes colorless or flecked with black spots. If the warm bead in the O. F. is touched with KNO_3 a rose colored froth is obtained. If the beads are saturated they become jet black or opaque. If fused with soda the assay is bluish green and opaque when cold. All oxides and hydrous oxides of manganese above manganous oxide, MnO, evolve chlorine when heated with conc. HCl and the solution becomes green.

MERCURY, Hg

Mercury is the only metal liquid at normal temperatures. It is readily distilled in the C. T. and O. T. and collected in metallic drops. The faintest trace of the vapor whitens gold. A faint yellow coat is obtained when mercury minerals are fused on coal with bismuth flux. On a plaster tablet a volatile yellow and red coat may be obtained but if too highly heated the sublimate is black and yellow. In the C. T. with Na_2CO_3, or PbO, a mirror is obtained or a dusky band which may be rubbed into globules with a glass rod. Calomel, Hg_2Cl_2, blackens instantly with a few drops NH_4OH. Corrosive sublimate, $HgCl_2$, is changed to red HgO by solid NaOH when heated together in a matrass.

MOLYBDENUM, Mo

Molybdenum affords a yellowish green flame with borax in the O. F. The bead is yellow when hot and colorless when cold. In the reducing flame it is brown or black and opaque. With S.Ph in the O. F. the bead is yellowish green when hot and colorless when cold. In the R. F. it is emerald green. The beads when saturated may be crushed and placed on moistened unglazed paper. The paper will turn either brown or blue according to the amount of Mo present. If the beads are dissolved in cold dilute HCl and metallic Sn is added a blue solution will result which becomes brown upon heating.

Powdered molybdenum minerals moistened with conc. H_2SO_4 and evaporated nearly to dryness on porcelain afford on cooling dark blue spots. Molybdenite, MoS_2, is the most important ore. It is only slowly coated with metallic copper when placed in a solution of copper sulphate and in contact with a strip of zinc. Graphite under the same condition is quickly copper plated.

NICKEL, Ni

Metallic nickel is magnetic at ordinary temperatures, loses its magnetism at a high heat but picks it up again upon cooling. Nickel minerals reduced to the oxide upon coal become magnetic. The borax bead in the O. F. is violet when hot and a pale reddish brown when cold. In the R. F. they are at first cloudy and with prolonged flaming become clear and colorless. With the S.Ph in both the O. F. and the R. F. the bead is red when hot and yellow when cold. When this bead is treated on coal with metallic tin it becomes colorless. Sodium hydroxide, NaOH, in the absence of NH_4OH precipitates an apple green $Ni(OH)_2$. A more delicate test for nickel is to make the solution alkaline with NH_4OH, filter and add to the filtrate a few drops of an alcoholic solution of dimethylglyoxime. A crimson color and precipitate results.

INTERFERENCES

Ores containing arsenic should be carefully roasted before making the bead tests. Alloys should be roasted with borax as long as the assay is colored. A little lead may be added in making the fusion. When the borax is no longer colored the mass may be tested with S.Ph in the O. F. when if nickel is present the bead is red when hot and yellow when cold. Beads rich in cobalt sometimes require several dilutions with borax before the blue disappears entirely.

NITRIC ACID, HNO_3

All nitrates heated in a matrass with $HKSO_4$ and copper foil will liberate HNO_3 which attacks the Cu and sets free NO_2 recognized by its brown vapor. If filter paper is moistened with a solution of ferrous sulphate and brought in contact with the fumes it will turn brown.

PHOSPHORUS, P

The flame of phosphorus is momentarily a greenish blue. It is intensified by conc. H_2SO_4.

Phosphates fused with magnesium ribbon on coal and the fused mass moistened with H_2O will evolve the offensive odor of phosphine, PH_3.

Phosphates dissolved in HNO_3 will yield a yellow crystalline precipitate with the molybdic solution, ammonium molybdate, $(NH_4)_2\ MoO_4$, dissolved in dil. HNO_3. The precipitate is best effected at a temperature of about 84 degrees.

PLATINUM, Pt.

Platinum is insoluble in any single reagent. It is readily soluble in aqua regia. Potassium chloride added to this solution will precipitate potassium chlorplatinate K_2PtCl_6 which is crystalline, yellow and insoluble in C_2H_5OH.

POTASSIUM, K

The flame of potassium salts is violet except in the borates and phosphates.

INTERFERENCES

Sodium imparts a persistent yellow color to the flame. This is absorbed by blue glass while the violet ray of K is transmitted. If cadmium is present a borax bead may be made if nickel oxide which will become blue in the presence of potassium compounds. When lithium is present and the flame viewed through blue glass it is a bluish green. When a blue strip of celluloid is used the K ray is a blue violet, the Na ray is absorbed, the Ca ray is a greenish yellow and the Li ray is absorbed.

SELENIUM, Se

Selenium burns readily with an indigo blue flame and imparts the strong offensive odor of decomposing horseradish. When fused in the closed tube it affords brown fumes and a steel gray sublimate. On coal there is often a red border to the sublimate. When fused in the R. F. with soda on charcoal, the fused mass transferred to a silver coin and moistened with water, a black stain appears of silver selenide.

SILICON, Si

Silicates vary widely in their behavior with reagents. Many silicates dissolve in HCl with a separation of gelatinous or slimy silica. Some dissolve in conc. H_2SO_4 with a separation of scales of silica. When the powdered mineral is fused with one part of Na_2CO_3 and one part of K_2CO_3 on platinum foil, dissolved in dilute HCl and partially evaporated, a jelly like substance is observed. When fused with conc. H_2SO_4 and powdered fluorite, CaF_2, and the escaping fumes passed into a drop of water held in the loop of a platinum wire, a jelly of SiO_2 forms on the water. When silicates are fused with borax in the loop of a platinum wire a skeleton of silica is usually observed in the bead.

When treated with S.Ph in the above manner silicates usually leave a translucent mass in the shape of the original fragment treated. The S.Ph may be added to the borax bead and reheated. The bead becomes milky or opaque white.

SILVER, As

Silver minerals when roasted on charcoal are readily reduced to soft, malleable, silver white buttons of metallic silver. Volatile acid radicles should be eliminated by roasting before treating the product in the R. F. If the buttons are dissolved in HNO_3 and HCl added to the solution a white curdy precipitate of AgCl soluble in NH_4OH, is obtained. In rare instances a red sublimate of Ag_2O may be obtained on charcoal.

Sodium, Na

Sodium is readily recognized by its strong, persistent yellow flame. This flame must not be confused with the momentary flash of yellow that comes from the abundance of sodium particles in the laboratory.

Strontium, Sr

Strontium minerals impart a bright crimson color to the flame. This color is intensified by moistening with HCl. When fused with Na_2CO_3 on coal the insoluble mass sinks into the coal. In this respect strontium minerals behave like barium minerals and unlike calcium minerals. The borax and S.Ph beads are clear and colorless but can be flamed opaque.

Interferences

Barium and lithium are the two interfering elements. If barium is present the flame may be momentarily red but it is quickly changed to a brownish yellow. If lithium is present fuse the mass with $BaCl_2$. The lithium flame remains unchanged.

Sulphur, S

Sulphur can be easily identified by several different methods. It burns with a blue flame emitting the odor of a burning match.

Most sulphides heated in a closed tube give a sublimate of sulphur, which is lemon to straw yellow when cold. This sublimate may be melted and made brown or black by higher temperatures. In the open tube sulphides give the odor of SO_2. Roasted alone on charcoal they give the odor of SO_2. Most sulphides, but not all, when treated with HCl evolve H_2S which gas turns black a piece of filter paper moistened with either silver nitrate or lead acetate. Sulphides when treated with HNO_3 afford a separation of spongy porous sulphur which floats on the surface of the liquid.. All sulphides when fused with Na_2CO_3, and the fused mass transferred to a silver coin and moistened with water, afford a brownish black to black stain of Ag_2S. When fused with one part of Na_2CO_3 and one part of powdered quartz the fused mass will be either yellow or red. As the sulphates respond also to the hepar test it is well to fuse the mineral with Na_2CO_3 on platinum foil before transferring to a silver coin. If the reaction is positive the mineral is a sulphide for the sulphates are not reduced by Na_2CO_3 on Pt foil.

TANTALUM, Ta.

The tantalates may be fused with $HKSO_4$, the fused mass dissolved in H_2O and granulated tin added. The solution becomes a light blue which disappears rapidly upon dilution. Niobates treated in the same way give a blue solution far more permanent in color upon dilution.

TELLURIUM, Te

Tellurium melts easily and burns with a blue flame to TeO_2 which volatilizes in R. F. with a pale green flame. On charcoal the sublimate is white with a red or dark yellow border. In the O. T. tellurium and the tellurides afford a white tear drop like sublimate of TeO_2. If the fumes of TeO_2 are collected on unglazed porcelain the resulting gray or brown film may be rendered crimson by heating with a few drops of conc. H_2SO_4. Tellurides when fused with a bismuth flux on a plaster tablet afford a purplish brown sublimate. Tellurides when heated with conc. H_2SO_4 afford a reddish violet solution. This color may be destroyed by dilution with water or by too intense heat.

TIN, Sn

Metallic tin fuses easily on charcoal and yields a sublimate of SnO_2 which is yellow when hot, yellowish white when partly cold, and white when cold. This sublimate is unchasable and cannot be mechanically blown from the coal but if moistened with the nitrate of cobalt and reheated the sublimate becomes bluish green, at least in spots. Metallic tin is insoluble in conc. HNO_3 but is oxidized to metastanic acid, H_2SnO_3, which is white, heavy and insoluble.

Cassiterite, SnO_2, the most important ore of tin, may be pulverized, the powder rolled up in metallic sodium and heated on charcoal. The sublimate of SnO_2 results. When one part of the mineral, two parts of Na_2CO_3 and one part of pulverized charcoal are intimately mixed and fused on charcoal a sublimate of tin oxide SnO_2 is easily obtained. The assay when ground and washed yields particles of metallic tin. Pulverized cassiterite in contact with metallic Sn will give with HCl the oxide, SnO_2, by the reducing action of nascent H. The mineral becomes coated with a thin layer of metallic tin, which if treated in the O. F. will yield the characteristic sublimate.

TITANIUM, Ti

Titanium minerals fused with borax in the O. F. become yellow in the R. F., when saturated reddish brown if iron is present. With S.Ph in the O. F. yellow. In the R. F. colorless when cold if iron is absent. This bead when fused with Sn on charcoal becomes violet. When to an HCl solution of titanium minerals H_2O_2 is added and powdered Na_2SO_3 until decolorized and allowed to stand a little while, a white flocculent precipitate is obtained. Titanium minerals may be fused with Na_2CO_3 and dissolved in moderately dilute H_2SO_4, 1:1. When this solution is cold, diluted with H_2O and a little H_2O_2 added, the solution becomes a pale yellow to orange according to the amount of Ti present. HCl solutions containing titanium turn tumeric paper orange red.

INTERFERENCES

If iron is present as in ilmenite, FeO,TiO_2, the S.Ph bead in the R. F. will be yellow when hot and reddish brown when cold.

TUNGSTEN, W.

Tungsten minerals, when other bases that color the bead are absent, give with borax in the O. F. a bead that is colorless when feebly saturated and yellow when highly saturated. In the R. F. the bead is yellow but brownish when cold. With S.Ph in the O. F. the bead is yellow when feebly saturated but colorless upon cooling. In the R. F. the bead is blue when iron is absent. If iron is present the bead is yellow to red. When powdered tungsten minerals are boiled with HNO_3, WO_3 separates out as a yellow powder. If tin is added a blue color results which is intensified by boiling. The color is due to the formation of the tungstate of tungsten, WWO_4.

URANIUM, U.

Uranium minerals give a borax bead in the O. F. that is yellow and in the R. F. yellowish green to green. When the bead is highly saturated it may be rendered black by flaming. With S.Ph the bead in the O. F. is yellow when hot and yellowish green when cold. In the R. F. the bead is emerald green but best seen when the bead is cold.

Uranium compounds when brought into solution with a mineral acid and NH_4OH added yield a canary yellow precipitate of uranyl hydrate.

Potassium ferrocyanide, $K_4Fe(Cn)_6$, precipitates uranium from its slightly acid solutions as a brown uranium ferro-cyanide which is changed to yellow potassium uranate, $K_2U_2O_7$ by the addition of KOH.

VANADIUM, V.

With borax in O. F. vanadium minerals afford a bead that is yellow or brownish yellow. In the R. F. the bead is emerald green. With S.Ph in the O. F. the bead is a dark yellow while hot and a light yellow when cold. In the R. F. it is brown when hot and emerald green when cold. When vanadates are fused with Na_2CO_3 and KNO_3, the fused mass dissolved in H_2O, and either HCl or H_2SO_4 and metallic Zn are added, the solution becomes blue, then green, and then violet.

When vanadates are dissolved in conc. HCl, alcohol added and the solution evaporated nearly to dryness and taken up with water, the solution is colorless to a light green. Upon the addition of H_2O_2 the solution becomes red or brownish red due to the formation of pervanadic acid, HVO_4.

A shorter test is to dissolve vanadates in conc. HCl, dilute with water and add hydrogen peroxide. The color obtained is red or reddish brown.

ZINC, Zn

Zinc fuses easily on coal yielding a sublimate that is yellow when hot, yellowish white when partly cooled and white when cold. If this sublimate is moistened with the nitrate of cobalt and reheated it becomes a bright green which is known as Rinmann's green. The sublimate is not volatile but it can be mechanically blown from the coal. A few drops of the nitrate of cobalt may be placed on the coal near the assay and the strong R. F. used to secure the green spots. The infusible and light colored silicates of zinc when heated and moistened with a solution of the nitrate of cobalt assume a blue color which must not be confused with the blue of aluminum compounds.

ZIRCONIUM, Zr

The borax and S.Ph beads for zirconium minerals in both the O. F. and the R. F. are colorless. The S.Ph bead when highly saturated in the R. F. may be rendered opaque white by flaming. The oxide of zirconium, baddeleyite, ZrO_2, when strongly ignited affords a light of dazzling brilliancy. Its HCl solution turns turmeric paper an orange red. Zirconium may be precipitated from its acid solutions by Na_2HPO_4 as a white precipitate of zirconium phosphate but titanium is also precipitated from its acid solution by Na_2HPO_4. Likewise its acid solutions turn turmeric paper orange red.

CHAPTER VI.

THE METALLIC MINERALS

The minerals treated in this chapter are only those found within the Commonwealth of Kentucky. In a few cases only are the metals themselves represented and the minerals therefore are the metals combined with acid radicles to form well-known mineral species. With one exception the silicates are all omitted and reserved for discussion in Chapter VII which includes the non-metallic minerals. The reason for including calamine in this chapter is that in some localities it becomes an important ore of zinc. The method of classification is not that proposed by Prof. James Dwight Dana who probably in his life time contributed more to the science of mineralogy in America than any other mineralogist but the metals are treated in the same order as they appear in qualitative chemical analysis. It is presumed that the majority of students who take up the study of mineralogy have had qualitative analysis and therefore this method of classification seems preferable. It therefore seems more logical to classify the metallic minerals from the standpoint of the metals themselves than from the standpoint of their acid radicles.

GROUP I.

Lead, Pb; silver, Ag; mercury, Hg; Precipitated by HCl as chlorides.

1—**Galenite, lead sulphide, PbS.** Galenite crystallizes in the isometric system in well defined cubes, cubo-octahedrons and occasionally in octahedrons. It may also occur massive and granular.

In color galenite is a pure lead gray. Its luster is metallic. The color of the fine powder is a pure lead gray. Its hardness varies from 2.5 to 2.75. Its specific gravity is 7.5. The cleavage is highly perfect and parallel with the faces of a cube, therefore cubical, and its fracture varies from even to sub-conchoidal. It is brittle and opaque.

Pyrognostics. In the O. T. evolves SO_2. Before the blowpipe B. B. on charcoal gives the odor of SO_2 and forms a buff sublimate of PbO on the coal. This sublimate is chasable around over the coal and reducible to minute globules of metallic lead. The buff sublimate may have a bluish white border due to the formation of lead sulphite, $PbSO_3$. Galenite is decomposed by conc. HNO_3 with separation of porous, spongy sulphur which upon continued boiling is completely oxidized to white insoluble lead sulphate, $PbSO_4$.

Differences. Galenite is distinguished from all other minerals by its highly perfect cubical cleavage and high metallic luster. If pulverized so that it passes through a 100 mesh sieve cubes of galenite may be observed through a tripple magnifier.

Remarks. All galenite is more or less argentiferous but it requires a fire assay to determine the silver content of any lead ore. Galenite is found with fluorite in the fluorspar veins of Western Kentucky and with calcite and barite in the veins of the Bluegrass Region of Central Kentucky. It is the most important ore of lead but no large tonnage of galenite has as yet been mined in Kentucky. Galenite occurs sparingly in scattered crystals and in cavities in some limestones and in some carbonate iron ores, (kidney ore, block ore).

2—**Cerussite, lead carbonate, $PbCO_3$.** Cerussite crystallizes in the orthorhombic system in forms tabular, prismatic, pyramidal, fibrous, massive and even earthy.

In color it shades from white to a grayish black and may even be green from traces of some copper salt. When pure and perfectly crystallized its luster is adamantine but it may be vitreous, resinous or even pearly. The color of the fine powder is white. Cerussite has a hardness of 3.25 and a gravity varying from 6.46 to 6.57. Its cleavage is distinct, fracture conchoidal and its tenacity is very brittle. Small thin crystals are sometimes transparent but in general the mineral is translucent.

Pyrognostics. In the C. T. the mineral decrepitates, evolves CO_2, turns yellow and at high temperatures a dark red which turns yellow upon cooling. B. B. fuses easily yielding a buff coat of PbO on the charcoal and reduces to soft ductile lead gray buttons of metallic lead. Cerussite is soluble in hot conc. HCl from which white crystals of $PbCl_2$ form upon cooling. These crystals of lead chloride are soluble in hot water.

Differences. Cerussite is readily distinguished from other carbonates by its high specific gravity and formation of crystals of $PbCl_2$ as HCl solutions cool.

Remarks. Cerussite is an ore of lead in certain localities. It occurs in the fluorspar district of Western Kentucky where it is formed by the action of carbonated waters upon galenite. The mineral is always of secondary origin and found in the upper portion of ore bodies.

3—**Pyromorphite, lead phosphate with lead chloride, $3(3PbO,P_2O_5)+PbCl_2$.** Pyromorphite crystallizes in the hexagonal system in forms prismatic, barrel-shaped, in groups of nearly parallel, prismatic crystals tapering to a point, mass-like interlaced fibers, and sometimes in globular and reinform masses.

In color pyromorphite may be white, yellow, orange, gray, green, or brown. Its fine powder is either white or pale yellow and in luster it is resinous. Cleavage appears only in traces and the fracture is uneven. Its hardness is 3.75 and specific gravity 6. The mineral is very brittle and its diaphaneity varies from translucent to opaque.

Pyrognostics. In C. T. it affords a white sublimate of $PbCl_2$ which is soluble in hot water. B. B. In the forceps it fuses at 1.5 coloring the flame bluish green. On charcoal it fuses without reduction to a globule which assumes on cooling a crystalline form. The sublimates on the coal are yellow near the assay from the formation of PbO and white at a greater distance from the formation of $PbCl_2$. With soda on coal pyromorphite affords a button of metallic lead. Fused with magnesium ribbon and moistened with water it yields the odor of PH_3. The mineral is soluble in HNO_3. A few drops of H_2SO_4 added to the solution give a white precipitate of $PbS.O_4$.

Differences. Pyromorphite differs from other lead minerals in fusing to a crystalline button without reduction. It differs from other phosphates in yielding with soda a lead gray, malleable, metallic button.

Remarks. Pyromorphite is a decomposition product of galenite, cerussite, etc., in the presence of waters bearing dissolved phosphates. It occurs in the zone of oxidation of lead-bearing mineral veins and is of secondary origin. It occurs in the Western Kentucky fluorspar district associated with galenite but its occurrence here is rare. In certain other localities it occurs in quantities sufficiently large to be treated as an ore of lead.

4—**Silver, Ag.** Native silver crystallizes in the isometric system in the form of cubes. The crystals are often distorted and elongated into acicular forms. It occurs also in arborescent forms, nuggets, grains, scales, threads and sheets, or thick and large plates.

Its color and streak are silver white but often grayish black from tarnish. Its luster is highly metallic. The hardness is 2.75 and the gravity when pure 10.5. The fracture is hackly. Silver is malleable, ductile and sectile and in diaphaneity opaque.

Pyrognostics. Silver fuses at 961° C. to a silver white malleable button. Normally it yields no sublimate on coal but occasionally it affords near the assay a dark red sublimate of Ag_2O. Silver is soluble in HNO_3 from which solution HCl precipitates a white curdy precipitate of AgCl.

Differences. Silver is distinguished from all other metals by its silver white color and its conductivity of electricity.

Remarks. In Canada it is the most important ore of silver. It is not known definitely that native silver occurs in Kentucky although it has been reported to occur in the Western Kentucky fluorspar district.

5—**Argentite, silver sulphide, Ag_2S.** Argentite crystallizes in the isometric system in cubes, octahedrons and dodecahedrons. It occurs also in masses, incrustations and in disseminated grains. When encased in galenite it is considered isomorphous with the galenite.

In color it ranges from a lead gray to a blackish lead gray and its streak is lead gray and shining. Its luster is metallic. Its hardness is 2.25 and its gravity ranges from 7.2 to 7.36. It is somewhat malleable and cuts like wax. Small subconchoidal fractures may be obtained. In diaphaneity it is opaque.

Pyrognostics. In O. T. it affords an odor of SO_2. On charcoal in O. F. fuses with intumescence. In the R. F. reduces to soft malleable button of metallic silver. Soluble in HNO_3 with a separation of spongy porous sulphur. From this solution HCl precipitates AgCl which is soluble in NH_4OH.

Differences. Argentite is the only ore of silver that is perfectly sectile and cuts like wax. It is readily distinguished from lead minerals by reducing to a button without the formation of a buff sublimate.

Remarks. It is formed as a primary mineral in fissure veins and as a secondary mineral in the zone of enrichment. Its occurrence in Kentucky is in the Western Kentucky fluorspar district where it is encased in the galenite of the fluorite veins. It has not yet been found in commercial quantities. A large number of assays of the galenite from the calcite and barite veins of the Bluegrass Region showed traces of silver. These assays were made in the laboratory of the Geological Survey, Lexington, Ky., by Dr. Robert Peter and Dr. A. M. Peter.

Other assays of galenite ores from the Western Kentucky fluorspar field in Crittenden and Livingston Counties were made during 1923 by Prof. L. W. Currier in the mineralogical laboratories of Syracuse University.

(Mercury, Hg. No ores of mercury are known to exist in Kentucky.)

GROUP II.

Bismuth, Bi; Copper, Cu; Cadmium, Cd; Arsenic, As; Antimony, Sb; Tin, Sn; Gold, Au; Platinum, Pt. Precipitated by H_2S in neutral or slightly acid solutions.

(Bismuth, Bi. No ores of bismuth are known to exist in Kentucky.)

6—**Copper, Cu.** Native copper crystallizes in the isometric system in cubes, dodecahedrons and tetrahexahedrons. It occurs also in beautiful arborescent forms, sheets, plates, grains, scales, wires, threads and sometimes in large masses. The largest single mass of native copper ever found in America was discovered in Michigan in 1857. It was 45 feet in length, 22 feet in width, 8 feet in thickness and weighed 420 tons. It was 90% pure copper and contained a considerable amount of silver.

The color of copper is copper red but it tarnishes on exposure to the atmosphere. Its streak is also copper red and the luster is metallic. The hardness is 2.75 and specific gravity 8.85. Copper is malleable, sectile and ductile but when arborescent copper is broken the fracture is hackly.

Pyrognostics. Copper fuses at 1083° C. to a copper red, malleable button which yields no sublimate on coal. Copper is rapidly dissolved by HNO_3 with the evolution of dense reddish brown fumes of NO_2. NH_4OH in excess renders this solution a deep indigo blue.

Differences. Native copper is distinguished from all other minerals by its copper red color and its red, metallic, shining streak. It somewhat resembles niccolite, $NiAs$, but this gives a strong garlic odor when roasted on charcoal.

Remarks. Native copper is an important ore of copper, especially in Michigan where the Calumet and Hecla mine has been the largest producer of native copper of any mine in the world. In Kentucky native copper occurs in small disseminated grains in veins traversing the High Bridge series, especially in the Russell Cave shaft in Fayette County. It is only sparingly disseminated in the veins.

7—**Chalcopyrite, copper and iron sulphide, $CuFeS_2$.** Chalcopyrite crystallizes in the tetragonal system in sphenoidal forms. It is commonly massive and granular, but may be compact.

Its color is a deep brass yellow often tarnished or iridescent. Its streak is greenish black and its luster metallic. The hardness is 3.5 and the gravity is 4.2. The fracture is uneven and the tenacity brittle. In diaphaneity it is opaque.

Pyrognostics. Chalcopyrite in C. T. affords a sublimate of S. In the O. T. the fumes of SO_2. On charcoal it evolves SO_2 and reduces to a button that is strongly magnetic from the iron content of the mineral. The roasted mineral moistened with HCl gives a bluish green flame. The mineral is soluble in HNO_3 with a separation of spongy porous S which floats on the surface of the liquid. The solution becomes green from the formation of the nitrate of copper, $Cu(NO_3)_2$. If NH_4OH is added in excess the solution becomes indigo blue.

Differences. Chalcopyrite is the only deep brass yellow mineral that yields readily to the point of a knife. It is often confused with pyrite, FeS_2, but this mineral will not yield to the point of a knife. H. 6.25.

Remarks. Chalcopyrite is the most important ore of copper and one that is most widely disseminated. It is usually a primary but may be a secondary ore. It often furnishes the copper for the enrichment of ore bodies at the lower levels. It occurs in Western Kentucky in the fluorite-lead-zinc district. It is also associated with calcite in the deeper limestones of Central Kentucky. It is not known to occur in Kentucky in commercial quantities.

8—**Malachite, hydrous basic copper carbonate, $CuCO_3$, $Cu(OH)_2$.** Malachite crystallizes in the monoclinic system in prismatic forms, but the forms are seldom distinct. The acicular prisms are often grouped in tufts and rosettes. It occurs also in massive forms as incrustations with surface tuberose botryoidal, or with structure divergent. It may occur even granular or earthy.

Its color is malachite green but its streak is always paler in color than the mineral itself. Its luster when definitely crystallized is adamantine. The fibrous forms are often silky. The luster is sometimes earthy. The hardness is 3.75, specific gravity is 4. The fracture is uneven. The tenacity brittle and in diaphaneity it ranges from translucent to opaque.

Pyrognostics. In the C. T. and O. T. malachite blackens and loses water. B. B. fuses easily at 2 coloring the flame a beautiful emerald green. On charcoal reduces to metallic copper with a loss of water and CO_2. The charcoal removes the remaining O as CO. The mineral is soluble in warm dilute HCl with a rapid effervescence. This solution is rendered a deep indigo blue by NH_4OH.

Differences. Malachite is distinguished from all other green minerals by its rapid effervescence in warm HCl. It is distinguished from other copper minerals by its malachite green color.

Remarks. Malachite is always secondary in origin. It is a most common oxidation product formed by the action of carbonated waters upon other copper minerals. It may occur in the zone of enrichment in ore bodies by the replacement of either limestone or dolomite. It occurs in Western Kentucky in the veins of fluorite, lead and zinc as an alteration product of chalcopyrite. It does not occur in sufficient quantity to be regarded as an ore.

9.—**Azurite, hydrous basic copper carbonate, $2CuCO_3$, $Cu(OH)_2$.** Azurite crystallizes in the monocline system, often in tabular forms. It may also occur massive and present many imitative shapes.

Its normal color is azure blue but it may be a Berlin blue. The streak is always blue but paler than the color of the mineral itself. Its hardness is 3.75 and specific gravity 3.8. Its fracture is conchoidal, tenacity brittle and its diaphaneity is translucent to opaque.

Pyrognostics. In the C. T. and O. T. loses H_2O and CO_2 and blackens. In the forceps fuses at 2 with an emerald green flame. On charcoal reduces to a globule of metallic copper. Azurite dissolves in warm dilute HCl with a rapid effervescence due to the escape of CO_2. NH_4OH gives the deep indigo blue coloration.

Differences. Azurite is distinguished from all other minerals by its azure blue color and effervescence with HCl.

Remarks. Azurite is a secondary mineral formed by the action of carbonated waters upon other copper minerals. It is often formed from chalcopyrite around old copper mines where it is associated with malachite. It should occur in the Western Kentucky fluorite district in association with malachite.

10—**Greenockite, cadmium sulphide, CdS.** Greenockite crystallizes in the hexagonal system in hemimorphic forms. It often occurs in minute forms encrusting crystals of calcite from which it may be removed like a powder. It is supposed to impart the resinous luster to sphalerite, the most important ore of zinc and to furnish the bright yellow color sometimes seen in smithsonite, the carbonate of zinc.

Its color is some shade of yellow, usually honey yellow. It may be citron, orange or bronze yellow. Its streak shades from an orange yellow to a brick red. Its luster if definitely crystallized is nearly adamantine but usually resinous. Its fracture is conchoidal and its cleavage distinct. In hardness it is 3.25 and in specific gravity 4.8. It is brittle and subtransparent.

Pyrognostics. In the C. T. it becomes a bright carmine red at a high heat but returns to the normal color upon cooling. In the O. T. it affords SO_2. Fused with Na_2CO_3 it responds to the hepar test. On charcoal it gives a reddish brown sublimate of CdO. The coating in thick layers may be brownish black and iridescent. The coat is volatile and is best seen on a plaster tablet. Greenockite is soluble in HCl with an evolution of H_2S.

Differences. Greenockite is readily distinguished from all other sulphides by its dense reddish brown fumes and sublimate on a plaster tablet.

Remarks. Greenockite occurs as crystals in the igneous rocks of Scotland. In some instances it incrusts sphalerite and calcite but more often the greenockite molecule is encased within the sphalerite. It occurs in the Western Kentucky fluorite-galenite-sphalerite district within the resinous sphalerite, as an orange yellow coating on the walls of the veins, in the cracks of the walls, and on the surface of smithsonite.

11—**Cadmium carbonate, $CdCO_3$.** The introduction of this compound which has no mineralogical name other than cadmium carbonate is not above criticism. The compound occurs intimately associated with smithsonite, $ZnCO_3$, with which it may be isomorphous. In roasting the ore the fumes of CdO are given off before those of the zinc. The color of the pure compound is white or yellowish white.

Pyrognostics. In the C. T. evolves CO_2. On charcoal loses CO_2, turns reddish brown to carmine red and then yields dense brown fumes of CdO soluble in HCl.

Differences. Distinguished from all other carbonates by its dense brown sublimate either on a plaster tablet or on charcoal.

Remarks. This product should be found in Western Kentucky in Crittenden County where smithsonite, $ZnCO_3$, has been mined as an ore of zinc.

(Arsenic, As; antimony, Sb; tin, Sn. As far as is known to the author these three bases do not occur in the metallic minerals of Kentucky.)

12—**Gold, Au.** Gold crystallizes in the isometric system in cubes and octahedrons. It occurs also in nuggets, grains, scales, wires, threads, plates. It may be dendritic or reticulated. Its color is golden yellow. The streak is golden yellow and shiny. The luster is highly metallic. The hardness is 2.75 and the specific gravity is 19.3 when pure. It is malleable, ductile and sectile with a hackly fracture. Its diaphaneity is opaque.

Pyrognostics. Gold fuses easily on charcoal, 1065.6° C., to a soft malleable golden yellow button. If a large percentage of silver is present the button will closely resemble white gold. Gold is insoluble in the mineral acids. Soluble in selenic acid and in aqua regia.

Differences. It is distinguished from all other minerals by its golden yellow color. Chalcopyrite and pyrite are often mistaken for gold. Chalcopyrite is brittle while gold is malleable and minute grains can be pressed out under a knife blade. Pyrite is 6.25 in hardness and does not yield to the point of a knife.

Remarks. Native gold is the most important ore of gold. It does not occur in Kentucky in commercial quantity.

GROUP III.

Iron, Fe; Aluminum, Al; Chromium, Cr. Precipitated as hydroxides by ammonium hydroxide. Also metals like titanium are included here.

13—**Iron, Fe.** Iron crystallizes in the isometric system, but it is usually found massive or in minute grains. Artificial crystals are usually dendritic. The color and the streak are both steel gray to iron black. The luster is metallic. Its hardness is 4.5 and its gravity is 7.55. The cleavage is perfect. The metal is malleable, but breaks with a hackly fracture and is opaque.

Pyrognostics. At a temperature between 1500 and 1600 degrees it fuses to a globule that loses its magnetism at a very high heat but picks it up again upon cooling. Iron is soluble in HCl. If HNO_3 is added to oxidize ferrous iron to ferric iron NH_4OH gives a reddish brown precipitate of $Fe_2(OH)_6$.

Differences. Iron is distinguished from all other metals by its high degree of magnetism both before and after heating.

Remarks. Native iron may be either terrestrial or meteoric. In meteoric iron nickel is always present in appreciable quantity and small percentages of cobalt appear in the analysis of metallic meteorites. Fourteen meteorites have been known to fall in Kentucky of which nine are siderites, that is, iron-nickel alloys.

14—**Pyrite, iron disulphide, FeS_2.** Pyrite crystallizes in the isometric system in cubes, octahedrons and pentagonal dodecahedrons. It is sometimes fibrous, reniform, globular and stalactitic. It is frequently massive and granular.

Its color is a pale brass yellow. The streak is either greenish black or brownish black. Its luster is metallic. The hardness is 6.25. It therefore is not cut by an ordinary pocket knife. Its gravity is 5. Pyrite has a conchoidal fracture, is brittle and opaque.

Pyrognostics. Pyrite yields a sublimate of S in the C. T. The odor of SO_2 in the O. T. In the forceps fuses at 2 with a loss of SO_2. On charcoal it loses sulphur, which burns with a blue flame to SO_2, and reduces to a magnetic globule. Pyrite is insoluble in HCl but readily soluble in HNO_3 with a separation of spongy, porous sulphur.

Differences. Pyrite is easily distinguished from chalcopyrite for chalcopyrite has a hardness of 3.75 and can be easily cut with a knife. Chalcopyrite is also a deeper brass yellow. It need not be confused with gold for gold is malleable while pyrite is brittle.

Remarks. Pyrite is widely distributed in nature. It is widely distributed in Kentucky in phases of all rock formations but especially abundant in the shales and coals. It occurs as an objectionable accessory mineral in building stones. It is not an ore of iron nor does it occur in Kentucky in sufficient quantity to be used as a source of sulphur.

15—**Marcasite, iron disulphide, FeS_2.** Marcasite crystallizes in the orthohombic system in forms usually tabular, often in stalactites with radial structure, in spheroidal masses with radiating structure, in reniform, hepatic, capillary and cockscomb types.

Marcasite is of pale bronze yellow color which deepens on exposure to the atmosphere. It is frequently called white iron pyrites. Its streak is grayish or brownish black and its luster is metallic. Its hardness is 6.25 and its specific gravity 4.9. It is very brittle. Its fracture is uneven and its diaphaneity opaque.

Pyrognostics. In the C. T. it yields a sublimate of sulphur. In the O. T. SO_2. In the forceps fuses at 2 with a loss of S. On charcoal reduces easily to a strongly magnetic button. Decomposed by HNO_3 with a separation of spongy, porous sulphur. From this solution NH_4OH throws down reddish brown $Fe_2(OH)_6$.

Differences. It differs from pyrite in its paler color and often in its radiating structure.

Remarks. Marcasite is very unstable and therefore subject to rapid decomposition. On account of the rapidity with which it decomposes it is one of the most dreaded injurious accessory minerals in building stones. It is widely distributed in the rocks of Kentucky but nowhere does it occur in quantity sufficient for the extraction of its sulphur content. It is not an ore of iron.

16—**Melanterite, hydrous ferrous sulphate, $FeSO_4,7H_2O$.** Melanterite crystallizes in the monoclinic system in forms short and prismatic, often in fibrous, stalactitic and concretionary forms. It may be massive or pulverulent.

When freshly crystallized the color is green but it turns greenish white or yellowish white on exposure to the atmosphere. The streak is white and the luster vitreous. Its hardness is 2, sufficiently soft to be scratched with the thumb nail. Its specific gravity is 1.89. Its fracture is uneven. It is brittle and translucent.

Pyrognostics. In the C. T. it yields H_2O, SO_2, and at a high temperature SO_3. In the forceps it loses H_2O, turns brown, then red, then black and becomes magnetic. On the charcoal reduces to a magnetic mass. It is soluble in twice its weight of water and from this solution NH_4OH precipitates green ferrous hydroxide, $Fe(OH)_2$.

Differences. Melanterite is the only mineral soluble in twice its weight of water that instantly blackens a tincture of nutgalls. Even the powder itself turns the solution black.

Remarks. Melanterite is always secondary in origin formed from the breaking down of the sulphides of iron and sulphides of other minerals containing iron. It is often found as a whitish efflorescence on sulphide bearing rocks in Kentucky. It dissolves in circulating ground water and imparts to them a taste suggestive of alum.

17—**Siderite, iron carbonate, $FeCO_3$.** Siderite crystallizes in the rhombohedral division of the hexagonal system. Its forms are often rhombohedrons with curved faces. It may also occur in cleavable granular masses, in botryoidal forms, globular froms, and even compact oolitic and earthy. Clay iron concretions are siderite in spheroidal form with a mixture of clay, sand, limonite, hematite, or even the oxides of manganese. Blackband is siderite mixed with clayey matter and carbonaceous matter.

Siderite is normally some shade of gray in color but it may be white or either brown or red upon exposure to the atmosphere. Its streak is white. Its luster is vitreous but sometimes inclined to be pearly on the cleavage faces. Its hardness is 3.75 and the specific gravity is 3.85. The tenacity is brittle, fracture uneven, diaphaneity translucent.

Pyrognostics. In the C. T. decrepitates, loses CO_2, turns black and becomes magnetic. In the forceps it fuses at 4.5 and becomes magnetic. B. B. on charcoal loses CO_2, turns black, becomes magnetic and fuses with difficulty. The borax head in the R. F. is bottle green. Siderite is soluble in warm HCl with effervescence. NH_4OH precipitates from this solution green $Fe(OH)_2$. If any HNO_3 is present a part of the iron will be oxidized to ferric conditions and the precipitate will be in part reddish brown, $Fe_2(OH)_6$.

Differences. Siderite is distinguished from all other iron minerals by turning turbid a drop of $Ba(OH)_2$ in the loop of a Pt wire as the mineral passes into solution with warm HCl. It is distinguished from all other carbonates by becoming strongly magnetic on charcoal.

Remarks. Siderite is an ore of iron. In the U. S. it furnishes about 1% of the pig iron. In England it furnishes over 50 per cent. When containing manganese it is used in the manufacture of ferromanganese and spiegeleisen. Siderite ores have been worked in several sections in Kentucky for the manufacture of pig iron. One of the most interesting of these deposits is the oolitic siderite of the Preston Ore Banks, Bath County. The decomposition of siderite has given rise to much of the limonite of Kentucky.

18—**Vivianite, hydrous ferrous phosphate, $3FeO,P_2O_5,8H_2O$.** Vivianite crystallizes in the monoclinic system in prismatic forms. The crystals may be flattened and vertically striated, and may occur in stellate groups. It often occurs replacing the organic matter in bones, horns, shells, roots. The structure may be fibrous or earthy. The color of vivianite ranges from white to indigo blue to green, which is intensified by exposure to the atmosphere. Its streak is white when the mineral is fresh but upon exposure it quickly turns to blue and then indigo blue. The mineral is sectile but somewhat flexible in thin layers. Its hardness is 1.75 and specific gravity 2.63. The mineral is normally translucent but becomes opaque upon exposure.

Pyrognostics. In the C. T. vivianite loses neutral H_2O and whitens. In the forceps fuses easily at 1.5, coloring the flame bluish green. The green flame is best seen by moistening the mineral with H_2SO_4. On charcoal it reduces to a magnetic globule. Fused with magnesium ribbon on coal and the fused mass moistened with H_2O the strong, offensive odor of phosphine, PH_3, is observed. Soluble in HCl without effervescence. Ammonium molybdate precipitates the phosphoric acid from solutions in HNO_3 as yellow, crystalline ammonium phosphomolybdate.

Differences. Vivianite is distinguished from other phosphates, save dufrenite, by its reactions for iron, and from dufrenite by its color, for dufrenite is normally leek green and its streak is siskin green. It is a ferric phosphate $2Fe_2O_3$, P_2O_5, $3H_2O$.

Remarks. Vivianite is not an ore of iron. It can be made an available source of phosphoric acid when it occurs in sufficient quantity. It occurs in Kentucky in the Jackson Purchase, replacing stems and roots. It is always of secondary origin. It occurs also in Floyd County on the Louisa Fork of the Big Sandy River.

19—**Hematite, iron sesquioxide, Fe_2O_3.** Hematite crystallizes in the rhombohedral division of the hexagonal system. It also occurs in columnar, botryoidal, stalactitic, lamellar, compact, granular and friable masses. When the individual grains are about the size of the egg of a brook trout the ore is called oolitic. When in scales like plates of mica it is called micaceous hematite. When in a fine red product that can be mixed with oil and used direct as paint it is called red ocher.

The color of hematite may be a bright red or steel gray or iron black. The streak ranges from a cherry red to a blood red and as it passes into turgite the streak becomes reddish brown. The luster is metallic and sometimes splendent. Its hardness is 6, and its specific gravity is 5.1. The cleavage is indistinct, the fracture uneven, tenacity brittle and diaphaneity opaque.

Pyrognostics. In the C. T. unaltered. The bright red varieties darken but the red color returns upon cooling. B. B. infusible. On charcoal with R. F. it becomes strongly magnetic. With borax in the O. F. red when hot, yellow when cold in R. F. a bottle green bead. With Na_2CO_3 on charcoal reduces to a gray, magnetic, metallic powder. It is soluble in conc. HCl.

Differences. Hematite is readily distinguished from all other minerals by its cherry red to blood red streak. Its crystallization distinguishes it from all the hydrous oxides of iron save gothite, for these never crystallize and gothite is distinguished by its brownish yellow streak.

Remarks. Hematite is the most important metallic mineral in the world. The value of the pig iron and steel manufactured annually from it would exceed the value of any other metal extracted from all its ores. Its origin is the action of iron secreting bacteria, the dehydration of the hydrous oxides of iron and the breaking down of other iron minerals. In Kentucky it has been mined from the Clinton formation of Bath County where it is known as flaxseed ore on account of its flattened oolitic grains.

20—**Turgite, hydrous iron sesquioxide, $2Fe_2O_3,H_2O$.** Turgite never crystallizes, therefore it is without crystal system, crystal form, and cleavage. It occurs in forms that are massive, fibrous with fibers diverging, botryoidal, stalactitic and earthy. When red and ocherous it constitutes the red ocher of commerce.

The color of turgite ranges from a reddish brown to a reddish black. Its streak is reddish brown and the luster is submetallic. Its hardness is 5.5. Its specific gravity is 4.39. It is brittle and opaque.

Pyrognostics. In the C. T. it yields water and blackens and sometimes decrepitates violently. With soda on charcoal it reduces to a gray, magnetic, metallic powder. With borax in R. F. the bead is bottle green. It is solvent in conc. HCl.

Differences. It is distinguished from hematite and gothite by its failure to crystallize and from limonite by its deeper colored streak and flying to pieces when heated in a closed tube.

Remarks. It can be formed by the hydration of hematite and the partial dehydration of limonite. It is an ore of iron. In Kentucky it occurs in the Cumberland River iron ore deposits of Lyon and adjacent counties.

21—**Limonite, hydrous iron sesquioxide, $2Fe_2O_3,3H_2O$.** Limonite like turgite never crystallizes. It often occurs in stalactitic botryoidal and mammillary forms with a fibrous structure. Also massive, granular or earthy.

In color it ranges from ocher yellow through brown to nearly black. Its streak is reddish brown, yellowish brown or even yellow for the yellow ocher. Its luster may be dull or earthy, or silky. Its hardness is 5.25. Its specific gravity is 3.8 Its fracture is uneven. Its tenacity brittle.

Pyrognostics. Limonite loses much H_2O in the closed tube and darkens B. B. It loses H_2O and becomes magnetic. On charcoal it reduces to a gray, magnetic, metallic powder. With borax the bead in the R. F. is bottle green. With S.Ph a skeleton of silica is often observed. With HCl there often re-from minute grains of sand.

Differences. It is distinguished from the other hydrous oxides of iron by often leaving a siliceous or fibrous residue when dissolved in conc. HCl. Also from the ores of other metals by its yellowish brown streak and bottle green bead.

Remarks. Limonite is an important ore of iron. It is always secondary in origin resulting from the alteration of other iron ores or minerals containing iron. It is very widely distributed in nature. It is the source of the reddish brown and yellowish brown colors so often seen in rocks and soils and the walls of stone buildings. When these hydrated products are sufficiently concentrated they form good ore bodies. For Kentucky the limonite ore exceeds in value the hematite ore.

22—**Magnetite, iron ferrous ferric oxide, FeO, Fe_2O_3, or Fe_3O_4.** Magnetite crystallizes in the isometric system in octahedrons usually but sometimes in dodecahedrons. Cubes are very rare. Massive and granular forms either coarse or fine are common. It may occur also as a black magnetic sand.

Its color is iron black and its streak is black. Its luster is often highly metallic but it may even be submetallic. While cleavage is not distinct there is often observed an octahedral parting that might be mistaken for cleavage. Its hardness is 6 and its specific gravity is 5.1. Its fracture is uneven. Its tenacity brittle. Its diaphaneity opaque. It is strongly attracted by the magnet before heating.

Pyrognostics. B. B. almost infusible. In the O. F. it loses its magnetism. On charcoal with soda it reduces to magnetic particles. Its solvent is conc. HCl.

Differences. Magnetite is the only iron black mineral, rarely steel gray, that is strongly attracted by the magnet, both before and after heating. Many samples of magnetite will hold iron nails upon their vertical faces. These possess polarity and are called lodestones.

Remarks. Magnetite may segregate from a molten solution in masses more or less lenticular. The basic igneous rocks like the peridotite have furnished such segregations. It may be formed by the dehydration of the hydrous oxides of iron and their partial reduction to the ferrous condition. Reduction of hematite also yields it. It is an ore of iron in many localities but not in Kentucky. It occurs most abundantly within the state in the eastern and western peridotite dikes.

23—**Ilmenite, iron and titanium oxides, FeO,TiO_2.** Ilmenite crystallizes in the rhombohedral division of the hexagonal system usually in thick tabular forms but sometimes in acute rhombohedrons. It may be massive, compact, in grains or sand.

The color of ilmenite is iron black while its streak is submetallic to a brownish red. Its luster is sub-metallic. Its hardness is 5.5 and its specific gravity 4.75. Its fracture is uneven. Its tenacity brittle. Its diaphaneity opaque. It is faintly attracted by the magnet before heating.

Pyrognostics. In the C. T. and O. T. there is no change. B. B. infusible but in the reducing flame it is slightly rounded on the thin edges by prolonged blowing. With borax in the O. T. it reacts for iron. With S.Ph in the R. F. the bead becomes brownish red. This bead fused with Sn on charcoal becomes violet. The pulverized mineral when heated with conc. HCl affords a yellow solution which upon boiling with tinfoil becomes blue or violet. The mineral is readily decomposed by fusion with $HKSO_4$.

Differences. Ilmenite is distinguished from magnetite by its faint magnetism before heating and by its HCl solution turning blue when boiled with tinfoil.

Remarks. It is a primary constituent as an accessory mineral in igneous rocks. In Kentucky it occurs in the peridotites where it is neither an ore or iron nor a source of titanium. Leucoxene is an alteration product from ilmenite often found microscopically in highly metamorphosed rocks.

24—**Alunogen, hydrous aluminum sulphate, $Al_2(SO_4)_3,18H_2O$.** Alunogen crystallizes in the monoclinic system in fibrous masses or crusts. It may occur in more or less massive forms.

The color of alunogen is normally white but it may be tinted yellow by iron or even red. The streak is white and the luster is vitreous, although some fibrous varieties show a silky luster. Its fracture is uneven to even. Its tenacity brittle. Its diaphaneity translucent.

Pyrognostics. In the C. T. yields much water and at a high temperature H_2SO_4. On charcoal the fused mass moistened with $Co(NO_3)_2$ assumes a deep blue. The solvent is H_2O. From this aqueous solution NH_4OH precipitates white gelatinous, $Al_2(OH)_6$.

Differences. It is readily distinguished from the potash alum by the absence of a violet flame of K. From the ammonium alum by failure to give the odor of ammonia when heated in a matrass with KOH or NaOH. Its taste is like that of common alum.

Remarks. Alunogen is not an ore of aluminum. It occurs in Kentucky in some of the outcrops of the shale beds where it has been derived by the action of decomposing sulphides of iron upon the aluminum compounds in the shale.

25—**Wavellite, hydrous aluminum phosphate, $3Al_2O_3,2P_2O_5,12H_2O$.** Wavellite crystallizes in the orthorhombic system but distinct crystals are rather rare. It commonly occurs in crystalline globular aggregates with radiating structure. The fibers are often delicately fine.

The colors of wavellite vary widely. The lighter colors like white, green, brown are the more common. It may be nearly black. Its streak is white and its luster may be vitreous, pearly or resinous. Its hardness is 3.5 and its specific gravity 3.32. Its cleavage is perfect. Its fracture is uneven. Its tenacity brittle. Its diaphaneity translucent.

Pyrognostics. In the C. T. it yields much water, the last of which will turn Brazil wood paper yellow from the presence of fluorine which etches the glass. In the forceps the wavellite swells often splits into fibrous forms and becomes infusible. If moistened with H_2SO_4 the flame is green from the phosphoric acid. If fused with magnesium ribbon on charcoal and moistened with H_2O, the odor of PH_3 is obtained. The solvent is HCl.

Differences. Wavellite is often distinguished from other aluminum minerals by its beautiful radiating structure and from all other aluminum bearing minerals not silicates by exmains a fibrous residue from vegetable matter or siliceous residue foliating when heated.

Remarks. Wavellite is not an ore of aluminum. It is found sparingly in Western Kentucky in the minerals of the kaolinite group.

26—**Rutile, titanium dioxide, TiO_2.** Rutile crystallizes in the tetragonal system in prismatic forms that are often acicular or thread like. The crystals are often vertically striated. The mineral may occur in compact forms or even massive and granular.

The color of rutile shades from a reddish brown to a deep red. The streak is a pale brown. The luster usually metallic to adamantine in transparent varieties. Its hardness is 6.25 and its specific gravity 4.2. Its cleavage is distinct. Its fracture uneven. Its tenacity brittle. Its diaphaneity transparent to opaque.

Pyrognostics. In the C. T. and O. T. there is no reaction. B. B. alone infusible. With S.Ph in the O. F. the bead is colorless. In the R. F. violet when iron is absent and brownish yellow when iron is present. If iron is present the bead should be treated with metallic Sn to prove the Ti. Rutile is insoluble but rendered soluble by fusion with NaOH, Na_2CO_3, or $HKSO_4$. If after fusion the assay is dissolved in HCl and tinfoil added a beautiful blue coloration is afforded.

Differences. Rutile is often distinguished by its fine needle like or hair like crystals, reddish brown in color. The coarser crystals are often distinguished by the trillings due to twining.

Remarks. The variety of rutile that occurs in Kentucky in the peridotites is octahedrite which crystallizes in regular octahedrons of the tetragonal system.

GROUP IV.

Cobalt, Co; Nickel, Ni; Manganese, Mn; Zinc, Zn. This group is precipitated in alkaline solutions by ammonium sulphide, $(NH_4)_2S$.

27—**Cobalt, Co.** This metal does not occur free and unalloyed in Kentucky. It does, however, appear in traces in the iron-nickel meteorites of the State. The metal is faintly magnetic before heating, retains its magnetism at a high temperature and is still magnetic upon cooling.

28—**Nickel, Ni.** Strictly speaking this metal does not occur as a mineral in Kentucky, but it does occur in the iron-nickel meteorites in alloy with iron. Nine true siderites, iron-nickel meteorites have been found in the State. Three aerolites, stony meteorites, with finely disseminated iron-nickel alloy. Two siderolites with a stony matrix of chondritic and large masses of iron-nickel alloy.

29—**Pyrolusite, manganese dioxide, MnO_2.** Pyrolusite crystallizes in the orthorhombic system, but probably the crystals are pseudomorphous after manganite, Mn_2O_3, H_2O. the crystals are often short and indistinct or radiating, needle-like fibers. It frequently occurs in massive, compact, stalactitic, dendritic forms and as velvety crusts. It occurs frequently in alternate layers with psilomelane.

The color of pyrolusite is normally iron black, but it may be steel gray. Its streak is either black or bluish black and its luster is metallic. Its hardness varies from 2 to 2.5 but it is usually sufficiently soft to soil the fingers. Its specific gravity is 4.8. Its cleavage is imperfect. Fracture uneven. Tenacity brittle and diaphaneity opaque.

Pyrognostics. In the C. T. it often yields a little water. It readily gives off oxygen which intensifies the glow of a splinter. If the pulverized mineral is mixed with $KClO_3$ in equal parts and heated in a matrass, oxygen is rapidly liberated. B. B. infusible. On the charcoal it is reduced to a metallic mass that may be magnetic from iron as an impurity. The saturated borax bead is jet black. The solvent is conc. HCl. The reaction is accompanied with a rapid evolution of chlorine.

Differences. Pyrolusite is distinguished from all other manganese minerals by the ease with which it soils the fingers and from minerals not oxides or hydrous oxides of manganese by the rapid evolution of chlorine when dissolved in conc. HCl.

Remarks. Pyrolusite is always secondary in origin. It results from the breaking down of other manganese minerals. It is found in Kentucky in many sedimentary rocks and in soils derived from their decomposition. Fine specimens of dendrite have been observed in the shales of Central Kentucky. It is an ore of manganese in many localities, but not in Kentucky. It occurs in Colmar, Bell County, Ky., containing 70 per cent of MnO_2, Experiment Station Laboratory No. 81787.

30—**Psilomelane, MnO_2+xH_2O.** With barium or potassium as replacing elements. It never crystallizes and therefore has no crystal system, crystal form or cleavage. It does occur in botryoidal masses, in reniform and stalactitic forms, and often in layers alternating with pyrolusite.

Its color is usually black but sometimes a dark steel gray. Its streak is brownish black and its luster metallic to submetallic. Its hardness is 5.5 and its specific gravity 4.2. The mineral has uneven fracture, is brittle and opaque.

Pyrognostics. In the C. T. most varieties yield water. All varieties must yield H_2O if the formula is correct, and all varieties afford oxygen upon ignition. Psilomelane is soluble in conc. HCl with a rapid evolution of chlorine and the formation of a green solution. If a green or bluish green color persists after the Cl has been driven off by heating it indicates the presence of Co, Ni, or Cu. A few drops of H_2SO_4 usually precipitates a little white insoluble $BaSO_4$. The mineral moistened with HCl usually gives a green flame from the barium content. If viewed through a blue glass a violet flash of potassium is generally seen. The saturated beads are jet black.

Differences. Psilomelane is distinguished from all other minerals by its smooth surface, its black color and hardness of 5.5. This superior hardness of 5.5 to other manganese minerals is distinctive. No other hydrous oxide of manganese carries barium.

Remarks. Psilomelane is an important ore of manganese. Perhaps the best known locality is Bahia, Brazil. It is always secondary in origin and in Kentucky it is a constituent in many soils derived from the disintegration of manganese bearing sediments. It has been found in Greenup County.

31—**Wad.** The composition is variable. It never crystallizes, but occurs as an earthy ocher of manganese. It is usually brownish black in color with a reddish brown streak, but both the color and streak are variable. The hydrous oxide of iron, limonite, is always present and wad passes by insensible gradations into limonite. The carbonates of copper, malachite and azurite are often present and afford beautiful green and blue crystals in the earthy matrix of wad. The oxides of cobalt and nickel are sometimes present and so wad graduates into asbolite or bog cobalt. Wad is always earthy, extremely friable and opaque.

Pyrognostics. In the C. T. yields much water. On charcoal with the fluxes reacts for both iron and manganese, soluble in conc. HCl with a rapid evolution of chlorine. NH_4OH added to this solution gives a reddish brown precipitate of $Fe_2(OH)_6$. If copper is present a deep indigo blue solution. If cobalt is present the borax bead in the R. F. is blue.

Differences. It is distinguished from all other species by its extreme brittleness and earthy character. Spheroidal aggregates adhere so feebly that the mass can be broken down to a powder in the fingers.

Remarks. Wad is always of secondary origin derived from the decomposition of sedimentary rocks containing manganese. It is widely disseminated in soils especially in bog areas. It does not occur in Kentucky in sufficient quantites to be a source of manganese.

32—**Sphalerite, zinc sulphide, ZnS.** Sphalerite crystallizes in the isometric system in the hextetrahedral class. The crystals are frequently highly complex and distorted. Its most common occurrence is in cleavable masses that may be either coarse or fine granular. It also occurs in foliated, fibrous, radiating, plumose and botryoidal forms. It may also be amorphous or even occur as a powder.

Sphalerite varies widely in color. When pure it is nearly colorless. Yellow is the most common color, but it may be brown or even black. The yellow variety is cadmiferous. The black variety is ferriferous and is known as black jack. The streak varies from white to a light yellow. The luster is resinous, but for the nearly white varieties adamantine. Its hardness is 3.75 and its specific gravity is 4. Its cleavage is highly perfect and parallel with the faces of a rhombic dodecahedron. Its fracture is conchoidal. Its tenacity brittle and its diaphaneity translucent.

Pyrognostics. In the C. T. a faint sublimate of S. In the O. T. odor of SO_2. In the forceps fuses with difficulty. On charcoal in the R. F. cadmiferous varieties give a sublimate that is at first reddish brown and then a sublimate that is yellow when hot, yellowish white when partly cold and white when cold. Moistened with the nitrate of cobalt, $CO(NO_3)_2$, the sublimate becomes a bright green. The sublimate can be mechanically blown from the coal and is soluble in HCl. Sphalerite dissolves in HCl with a rapid evolution of H_2S which blackens paper moistened with lead acetate.

Differences. Sphalerite is readily distinguished by its highly perfect rhombohedral cleavage, and in most instances by its resinous luster.

Remarks. Sphalerite is the most important ore of zinc. In the State of Kentucky it assumes the value of an ore. The cadmiferous resinous variety constitutes the ore in the Western Kentucky fluorspar district and the ferriferous variety the ore of the Bluegrass Region in North Central Kentucky. It is also found disseminated in some limestones and in cavities within them. It is common in the siderite ores.

33—**Goslarite, hydrous zinc sulphate, $ZnSO_4$, $7H_2O$.** Goslarite crystallizes in the orthorhombic system in long acicular forms. It may occur massive, stalactitic and pulverulent.

Its color when pure is white but it may be greenish, bluish, yellowish, reddish in color. Its streak is white and its luster vitreous. Its hardness is 2.25 and its specific gravity is 2. Its cleavage is perfect. Its tenacity brittle. Its diaphaneity transparent to translucent.

Pyrognostics. In the C. T. yields much H_2O. In the O. T. much water. B. B. on charcoal with soda reduces to particles of Zn which quickly oxidize and form the sublimate of ZnO that is yellow when hot and white when cold. The fused mass transferred to a silver coin responds to the hepar test for S. The solvent for goslarite is water and taste is astringent, metallic and nauseating.

Differences. Goslarite is readily distinguished from all minerals save sulphates by its metallic and nauseating taste. It is distinguished from other sulphates of the metals by its white color and its sublimate yellow when hot and white when cold.

Remarks. Goslarite is not an ore of zinc. It has been found sparingly associated with the cadmiferous sphalerite in the Western Kentucky fluorspar district. It is formed by the action of sulphated waters upon other zinc minerals, especially the carbonate smithsonite, or the oxidation of the sulphides of zinc.

34—**Smithsonite, zinc carbonate, $ZnCO_3$.** Smithsonite crystallizes in the rhombohedral division of the hexagonal system. When crystallized the faces are generally curved and rough but the mineral is rarely well crystallized. It occurs in reniform, botryoidal and stalactitic forms, as an incrustation, and as an impalpable powder.

The normal color of smithsonite is white but it may be greenish or even brown. Its streak is white and its luster is vitreous. Its hardness is 5 and its specific gravity 4.37. Its cleavage is highly perfect and its fracture uneven. Its tenacity is brittle and its diaphaneity translucent.

Pyrognostics. In the C. T. it loses CO_2, becomes yellow while hot but turns white upon cooling. B. B. in the forceps infusible. On charcoal reduces to elemental zinc which affords a sublimate that is yellow when hot and white when cold. This sublimate moistened with $CO(NO_3)_2$ and reheated becomes bright green. Solvent HCl.

Differences. Smithsonite is the only ore of zinc that dissolves in warm HCl with a rapid effervescence of CO_2. It is distinguished from other carbonates by its hardness of 5 and its gravity of 4.37.

Remarks. Smithsonite is an important ore of zinc. It may be formed by the action of carbonated waters upon other zinc minerals. It usually occurs in the calcareous rocks in veins and beds associated with galenite and sphalerite. It occurs as an ore in Crittenden County in the lead-zinc-fluorite mines.

35—**Hydrozincite, hydrous basic zinc carbonate, $ZnCO_3$, $2Zn(OH)_2$.** Hydrozincite occurs in massive and fibrous forms. Also as incrustations that may be concentric or agate-like. It may be reniform, pisolitic, stalactitic or even earthy.

Its color is normally white but may be yellowish or reddish. Its streak is white or shining. Its luster is vitreous. Its hardness is 2.25 and its specific gravity is 3.7. It is brittle and translucent.

Pyrognostics. In the C. T. it yields much water, turns yellow upon heating and returns to white upon cooling. With soda on charcoal reacts for zinc. Soluble in warm HCl with an evolution of CO_2.

Differences. Hydrozincite is distinguished from all other minerals save the carbonates by effervescence in warm HCl. It is distinguished from all other carbonates save smithsonite by yielding a sublimate when fused with soda. Not so yellow when hot and white when cold. It differs from smithsonite in yielding water in the closed tube.

Remarks. Hydrozincite is a basic zinc carbonate formed by the alteration of smithsonite which it somewhat resembles. It occurs in Western Kentucky associated with the lead and zinc deposits. Alone it is not regarded as an ore of zinc.

36—**Calamine, hydrous basic zinc metasilicate, $ZnSiO_3$, $Zn(OH)_2$.** Calamine crystallizes in the orthorhombic system in hemimorphic forms. It often forms drusy surfaces in cavities and often occurs in stalactitic, botryoidal, mammillary and fibrous forms. It may occur massive and granular.

The color and streak of calamine are normally white but the color may be greenish and is often brownish. Its luster is vitreous. Its hardness is 4.75 and its specific gravity is 3.46. When crystallized its cleavage is perfect, fracture uneven, tenacity brittle and diaphaneity subtransparent.

Pyrognostics. In the C. T. it yields water, whitens and decrepitates. B. B. practically infusible but fuses at 6 upon prolonged blowing. The ignited assay on coal moistened with $CO(NO_3)_2$ assumes a green color. Fused on charcoal with soda it yields a sublimate that is yellow when hot and white when cold. If moistened with $Co(NO_3)$, the characteristic bright green of zinc is obtained. With S.Ph yields a skeleton of silica. With HCl or HNO_3 or acetic acid yields gelatinous silica. It is also decomposed by strong KOH solution.

Differences. Calamine is distinguished from all other zinc minerals by gelatinizing with acetic acid. It differs from willemite, Zn_2SiO_4, by yielding water in the closed tube.

Remarks. Calamine is always of secondary origin resulting from the alterations of other zinc minerals especially sphalerite and smithsonite with which it is generally associated. It is an ore of zinc and occurs in Western Kentucky in the lead-zinc-fluorite district.

CHAPTER VII.

THE NON-METALLIC MINERALS

The chapter on the non-metallic minerals found in Kentucky includes 46 species. Some of these are very common while others are rare. The identification of the rare minerals has been possible only through the study of rock sections .003 of a millimeter in thickness under polarized light and a high magnification. Associated with some of the common minerals there should be discovered several species not listed here, as for instance anhydrite is a common associate of gypsum, but anhydrite so far as is known to the author has not been found in Kentucky.

This chapter is introduced by two non-metallic elements, graphite, C, and sulphur, S. The alkaline earths and the alkalies are treated in the order of their group separation because this seems to the author to be the more logical method of presentation. This is followed by silica and the silicates themselves. The silicates are arranged in the order given by Prof. James Dwight Dana which order is almost universally accepted by mineralogists today. The mineralloids are reserved for discussion in Chapter VIII.

THE NON-METALLIC ELEMENTS

Carbon, C, and sulphur, S.

37.—**Graphite, C.** Graphite crystallizes in the rhombohedral division of the hexagonal system in tabular, striated, six sided crystals with faces rarely distinct. It also occurs in foliated masses, columnar or radiated, scaly or slaty, granular to compact, and even earthy. It has been observed in globular concretions with radial structure but this form is rare.

The color of graphite is a dark steel gray or iron black with a steel gray streak. Its luster is metallic but sometimes it is earthy. Its hardness is 1.5 and its specific gravity 2.1. The basal cleavage is perfect. The thin laminae are flexible and inelastic. The fracture is uneven and the diaphaneity opaque. It is characterized by a very greasy feel and its conductivity of electricity.

Pyrognostics. In the C. T. many samples of graphite yield a sublimate of sulphur, S, from enclosed pyrite. Pure graphite will yield no reaction. The mineral is infusible before the blowpipe but in an atmosphere of oxygen at a high temperature it burns to carbon monoxide, CO, or carbon dioxide, CO_2. When fused with KNO_3 in a platinum spoon it deflagrates and becomes oxidized to K_2CO_3 which is soluble in H_2O. The element itself is insoluble in mineral acids.

Differences. Graphite is the only element that marks as a pencil on paper. The color of this streak is steel gray while that of molybdenite, MoS_2, which mineral it most closely resembles in color, is bluish gray. Graphite, when brought in contact with a strip of zinc in a solution of copper sulphate is very quickly copper plated while molybdenite under the same conditions is only slowly copper plated. The ease with which graphite soils the fingers is a distinctive test.

Remarks. The graphite of many sedimentary and metamorphic rocks is the direct result of the metamorphism of vegetable matter. E. Weinschenk attributes the origin of the graphite of Ceylon to the action of cyanogen compounds upon vapors charged with carbon dioxide. It has also been observed in meteorites. In Kentucky graphite has been found in the Elliott County peridotites. Either uncombined carbon or carbonaceous matter is the coloring constituent in the limestones, marbles and shales of Kentucky.

38—**Diamond, C.** The diamond crystallizes in the isometric system in the form of octahedrons, hexoctahedrons, rhombic dodecahedrons and cubes; also in spherical forms with a radial structure and rarely massive.

The diamond is normally colorless or white but it may be yellow, green, blue, red or even black. Its streak is white and its luster adamantine. Its hardness is 10 but the hardness of the crystalline variety bort is superior to that of the gem. Its specific gravity is 3.525. Its cleavage is highly perfect. Its fracture conchoidal. Its luster adamantine and its diaphaneity transparent.

Pyrognostics. In an atmosphere of oxygen at a high temperature the diamond burns to carbon monoxide, CO, which gas is burned to carbon dioxide, CO_2.

Differences. The diamond is distinguished from all other gem minerals by its superior hardness to all minerals and to all artificial products. It can be easily distinguished from a paste gem by immersing the two in cinnamon oil. The paste gem disappears while the diamond remains clearly visible because its index of refraction is 2.417, which is higher than that of the cinnamon oil.

Remarks. In the minds of most people the diamond is the most coveted jewel of to-day but the pure rubies of upper Burma have a greater value per carat than the diamond. Only one diamond has been reported from Kentucky. This was found on the farm of Henry Burris, in Russell County, near the Montpelier postoffice in Adair County. Its occurrence in this locality is a mystery for there are no rocks in the region that could normally furnish a diamond. The most likely place to find diamonds within the State is in the peridotite dikes of Elliott County for here the peridotite closely approximates in mineralogical composition to the kimberlite of S. Africa which is the original matrix of the diamond. Diamonds might also be found in the peridotites of Western Kentucky.

39—**Sulphur, S.** Sulphur crystallizes in the orthorhombic system in acute pyramidal forms, rarely in tabular forms. It has been observed massive and in spherical, reneform, stalactitic and stalagmitic forms.

Its color may be lemon yellow, straw yellow or honey yellow with a white streak. A student often reports the streak as yellow or yellowish white because the powder is not reduced fine enough. The luster of sulphur is resinous. Its hardness is 2. Its specific gravity 2.07. Its cleavage is imperfect. Its facture conchoidal. Its tenacity brittle. Its diaphaneity transparent to translucent. It is negatively electrified by friction and is itself a non-conductor of electricity.

Pyrognostics. In the C. T. sulphur melts at a temperature varying from 115 to 119 degrees Centigrade. The melt is first yellow, then brown, then black, but becomes yellow again upon standing. In the O. T. it is oxidized to SO_2, burns with a blue flame and emits the irritating odor of a burning match. It is ignited by the flame of a match. It is insoluble in water and the mineral acids but soluble in carbon disulphide from which upon evaporation by exposure perfect crystals of sulphur are often formed.

Differences. Sulphur is distinguished from all other minerals by burning at a low temperature, that of a burning match, to sulphur dioxide, SO_2., with its characteristic irritating odor. Also by crystallizing out from solution in CS_2 in perfect octahedrons of the orthorhombic system.

Remarks. Sulphur is often a product of volcanic emanation. It is reduced from solution by organic matter. It results from the decomposition and reduction of sulphides and sulphates and the decomposition of hydrogen sulphide by bacteria or by exposure to the air. It is found sparingly in the Western Kentucky fluorite veins where it appears to be an alteration product of the associated galenite.

GROUP IV.

Barium, Ba; Strontium, Sr; Calcium, Ca; Precipitated from their alkaline solution by ammonium carbonate.

40—**Barite, barium sulphate, $BaSO_4$.** Barite crystallizes in the orthorhombic system in tabular plates and prismatic forms. It may also occur massive and granular, even in earthy forms.

Its color is normally white but it may be gray, blue, yellow or red. Its streak is white and its luster vitreous. Its hardness is 3 and its specific gravity is 4.6. Its cleavage is perfect and both basal and prismatic. Its fracture is uneven. Its tenacity brittle and its diaphaneity ranges from transparent to opaque.

Pyrognostics. B. B. Barite fuses at 3 with a loss of SO_2 and at a higher temperature SO_3. The residue of BaO when moistened with H_2O is alkaline. When the mineral is pulverized and moistened with HCl the flame is green. When fused with Na_2CO_3 on charcoal the fused mass sinks into the coal. When cut out, placed on a silver coin and moistened with H_2O the coin is stained brownish black or black from the formation of Ag_2S. Barite is insoluble in water and the mineral acids.

Differences. Barite is distinguished from all other sulphates save lead, strontium and calcium by its insolubility in water. It is distinguished from lead sulphate, anglesite, by not reducing to a metallic button on coal. From calcium sulphate by sinking into the coal when fused with Na_2CO_3, and from strontium sulphate by yielding a green flame rather than a crimson flame.

Remarks. Barite is a widely distributed mineral. It may be formed by the action of decomposing sulphides upon the soluble salts of barium. It is deposited by mine waters in the boxes and pipes of certain coal mines. It occurs as a cement in certain sandstones. Its most common occurrence is with beds or veins of the metallic ores. It occurs in Kentucky in the veins and cavities in the limestones of the inner Bluegrass Region where it constitutes the chief mineral. According to Prof. L. W. Currier, its rank is third among the vein minerals in this district. It also occurs in the Western Kentucky fluorite veins. Witherite, the carbonate of barium appears to be wanting in Kentucky.

41—**Celestite, strontium sulphate, $SrSO_4$.** Celestite crystallizes in the orthorhombic system in forms tabular and prismatic, closely resembling the forms of barite. It also occurs in fibrous cleavable masses. It is sometimes globular and occasionally granular.

It is normally white in color but it may be bluish or purplish or even red. The streak is white and the luster vitreous. Its hardness is 3.25 and its specific gravity 3.96. Its cleavage is perfect both basal and prismatic. In one of the three directions the cleavage is less perfect than in the other two. Its fracture is uneven. Its tenacity brittle and in diaphaneity it ranges from transparent to subtranslucent.

Pyrognostics. B. B. celestite often decrepitates, loses SO_2, then SO_3 and the resulting residue when moistened with water reacts alkaline. It fuses at 3 to a white pearl, coloring the flame a bright crimson. The color of the flame is intensified by moistening with HCl. Fused with Na_2CO_3 the fused mass sinks into coal and reacts positive with a silver coin. The mineral is insoluble in acids.

Differences. Celestite is distinguished from all other insoluble minerals by its bright crimson flame when moistened with HCl. It is most often confused with barite but the green flame of barite is distinctive.

Remarks. Celestite may be formed by the action of decomposing sulphides upon the soluble salts of strontium. It is commonly associated with the limestones and sandstones and occasionally with the metallic ores. It frequently occurs lining cavities that are geodetic in the limestones of Kentucky.

42—**Strontianite, strontium carbonate, $SrCo_3$.** Strontianite crystallizes in the orthorhombic system in prismatic forms that are often acicular or spear shaped. It may also occur in columnar, globular, fibrous, massive and granular forms. The fibres often diverge from a common center.

The color is often white but may be gray, yellow, brown, asparagus green or apple green. The streak is white and the luster vitreous. Its hardness is 3.75 and its specific gravity is 3.7. Its cleavage is nearly perfect, its fracture uneven, tenacity brittle, diaphaneity transparent to translucent.

Pyrognostics. B. B. strontianite fuses only on the thin edges but it intumesces and throws out pseudopodia or sprouts and becomes alkaline. The flame when the mineral has been moistened with HCl is a bright crimson. The mineral dissolves in warm HCl with a rapid evolution of CO_2 which turns turbid a drop of lime water held in the loop of a platinum wire. A few drops of concentrated H_2SO_4 added to this HCl solution will precipitate white insoluble $SrSO_4$.

Differences. Strontianite is distinguished from all other carbonates by its bright crimson flame and from all minerals not carbonates by effervescence with warm HCl. Its diverging crystals are often an aid in identification.

Remarks. The strontium carbonate molecule is often present with that of calcium carbonate in limestones and in aragonite. In Kentucky it occurs as an incrustation on barite in the Clark barite vein in Franklin County and the Johnson barite mine in Scott County.

43—**Gypsum, hydrous calcium sulphate, $CaSO_4,2H_2O$.** Gypsum crystallizes in the monoclinic system in flattened or prismatic or acicular forms. The crystals are often swallow-tailed and beautiful. The rosettes in the caves of central Kentucky are among the most delicate of all the forms of gypsum. When the prisms extend at right angles to the walls that enclose them and the product has a luster suggestive of satin, the mineral is called satin spar. When in transparent plates easily separable from each other it is called selenite. Gypsum may also occur massive and granular.

The color is normally white but it may shade through normal colors even to black. Its streak is white. Its luster is vitreous, pearly and even satiny. Its hardness is 2. Its specific gravity is 2.32. Its cleavage is highly perfect for it can be separated into exceedingly thin folia. Its fracture is conchoidal. Its tenacity more or less brittle and the diaphaneity of the crystals is transparent.

Pyrognostics. In the C. T. it loses water and becomes opaque. In the O. T. loses water and becomes opaque. In the forceps fuses at 2.75 coloring the flame yellowish red or brick red. When heated on charcoal or in a test tube at a temperature not exceeding 260 degrees C. one-half molecule of water remains which enables the product to set when mixed with water. (Plaster of Paris). When fused with Na_2CO_3 the fused mass does not sink into the coal like the sulphates of barium and strontium. It responds positive in the hepar test. It is soluble in conc. HCl from which solution crystals of gypsum separate out upon cooling.

Differences. Gypsum is readily distinguished by its specific hardness of 2. It is sufficiently soft to be easily scratched with the thumb nail. Its yellowish red flame distinguishes it from all other sulphates save anhydrite, $CaSO_4$. The abundance of water which gypsum yields and the traces of water which anhydrite sometimes gives are distinctive differences.

Remarks. Gypsum forms most beautiful rosettes on the ceilings and walls of some of the limestone caves of Edmonson County. It occurs in bedded deposits in the Niagara shales. It is particularly abundant as gypsum, var. selenite, in the shales on the east side of the Cincinnati Arch. Occasionally good crystals of gypsum are found in the cavities of the iron ores of both

Eastern and Western Kentucky. Although gypsum is valuable as a fertilizer and as a retarder in the setting of Portland cement it is not known that it occurs in commercial quantities within the State.

Nearly pure white, in small crystals and fine powder. In nodules in a bed of marl.—Jas. Montgomery, Elizabethtown, Ky., No. 1996.

Small crystals in brownish clay. Looks as if it had come from between layers of limestone or other rock. W. A. Dunning, Cobb, Caldwell Co., No. 8872.

Imperfectly crystallized plates and imperfect rosettes. Sloan's Valley, Cave, Pulaski Co., Ky. Prof. Miller, 80797.

44—**Calcite, calcium carbonate, $CaCO_3$.** Calcite crystallizes in the rhombohedral division of the hexagonal system in crystals much varied in habit. The forms range from obtuse to acute rhombohedral, from thin tabular to long prismatic, and scalenohedral forms of great complexity. It also occurs in stalactitic, stalagmitic, columnar, tuberose, nodular, and imitative forms. In coarse and fine fibers, lammelar forms, coarse granular to impalpable and even compact to earthy.

Iceland spar is the variety that shows double refraction in the highest degree. Dogtooth spar is an acute scalenohedral form.

Nail head spar has the form suggestive of the head of a large nail.

Satin spar is fine fibrous with a satiny luster. It differs from the fibrous gypsum in that it effervesces in cold dilute HCl.

Shell marl may or may not contain the fragments of fresh water shells. It usually contains some clay.

Chalk consists largely of the hollow shells of rhizopods. It is soft enough to write on a blackboard.

Coquina consists of broken fragments of shells cemented together by calcium carbonate.

Travertine is the variety formed from springs and rivers by the relief of pressure and the evaporation of the solvent.

Mexican onyx is the variety distinguished by its translucency, fineness of texture, delicacy of colors, and often beautifully banded.

The individual grains of all the various types of limestones and marbles may be included here. All calcium carbonate is crystalline and that in the metamorphosed limestones and dolomites, crystallized.

The normal color of calcite is white but the entire range of the primary colors may be represented. The purple tinted calcite crystals of Sterling Bush, N. Y., are objects of great beauty. The streak is white but when much clayey matter is present it is sometimes grayish. Its luster is normally vitreous, but the finely fibrous varieties have a silky or satiny luster and the luster may also be dull or earthy. Its hardness is 3 and its specific gravity is 2.71. Its cleavage is highly perfect and parallel with the faces of a rhombohedron. Its fracture is uneven. Its tenacity brittle. Its diaphaneity transparent to opaque.

Pyrognostics. In the O. T. certain varieties will decrepitate and all varieties yield CO_2 if the temperature is high enough. B. B. it is infusible but when moistened with HCl the flame is a bright yellowish red or brick red. On charcoal calcite reduces to lime by the loss of CO_2 and the residue reacts alkaline. If the assay is flamed for some little time the residue becomes strongly luminous. The saturated borax bead can be flamed opaque white. Calcite is soluble in cold dilute HCl with a rapid effervescence due to the escape of carbon dioxide.

Differences. Calcite is distinguished from all other minerals save aragonite by its rapid effervescence in cold dilute HCl. Aragonite falls to pieces before the blowpipe while calcite does not. Pulverized calcite when boiled with $Co(NO_3)_2$ shows little if any change in color.

Remarks. Calcite is a very widely disseminated mineral. It is the essential constituent in all limestones and calcite marbles. It is often the cement binding sand grains together. It forms beautiful stalactites in Luray caverns of Virginia and the numerous caves in Edmonson and Hart Counties, Kentucky. It is the ganque mineral in many important metallic veins. Also the ganque mineral of fluorite in both Central and Western Kentucky. The Chinn calcite mine at Mundy's Landing, Mercer County, formerly operated by the Chinn Mining Company, is perhaps the largest calcite vein within the state. Limestones and marls are extensively used to enrich soils. When pure and perfectly crystallized it is of great value in the manufacture of petrographic microscopes, saccharimeters and other optical instruments. It is also used in the manufacture of glass and in numerous other industries.

45—**Dolomite, calcium and magnesium carbonate, $CaCO_3$, $MgCO_3$.** Perhaps this formula is better expressed by $CaMg(CO_3)_2$. In the theoretical dolomite the calcium carbonate is 54.27 per cent and the magnesium carbonate 45.73. Dolomite crystallizes in the rhombohedral division of the hexagonal system often with curved faces. It may also be massive and granular with grains either coarse or fine or even amorphous.

Its color is white but all the primary colors may be represented. Its streak is white and its luster vitreous although in some varieties the curved face will be pearly. Its hardness is 3.75 and its specific gravity is 2.85. Its cleavage is perfect. Its fracture uneven. Its tenacity brittle and its diaphaneity ranges from transparent to translucent.

Pyrognostics. B. B. it is infusible. On charcoal it is reduced to CaO and MgO which react alkaline with litmus. When fused with Na_2CO_3 on Pt foil the mass does not become clear. When fused and moistened with the nitrate of cobalt and reheated the assay becomes pink. When treated with cold dilute HCl there is little or no effervescence. Often a little effervescence is observed due to grains of occluded calcite. In warm HCl dolomite effervesces freely.

Differences. Dolomite is distinguished from calcite by its superior hardness, 3.75, its higher specific gravity 2.85 and often when crystallized by the curved faces of its rhombohedrons. The difference in effervescence is distinctive for the purer forms, but dolomite limestones with less than 30 per cent of magnesium carbonate effervesce fairly freely.

Remarks. Many limestones are more or less dolomitic. The less soluble molecule of magnesium carbonate has been exchanged for the more soluble molecule of calcium carbonate. The nearest approach to a dolomite in the limestone series of Kentucky is found in the Oregon bed of the High Bridge series. Microscopic slides of this rock present the characteristics of a dolomite.

46—**Ankerite, calcium, magnesium and iron carbonate, $2CaCO_3, MgCO_3 FeCO_3$.** Ankerite crystallizes in the rhombohedral division of the hexagonal system. It may also occur massive with a granular texture, either coarse or fine. It may even be compact.

Its color may be white, gray or reddish but it turns brown or reddish brown upon exposure to the atmosphere. The manganiferous varieties may become black from the formation of MnO_2. The streak of the fresh mineral is white and the luster vitreous. Its hardness is 3.75 and its specific gravity is 3. Its cleavage is perfect. Its fracture uneven. Its tenacity brittle and its diaphaneity translucent.

Pyrognostics. B. B. on charcoal its behavior is much like dolomite. Its borax bead when manganese is absent is bottle green in the R. F. The saturated bead when Mn is present is jet black. It effervesces freely in warm dilute HCl.

Differences. Ankerite is easily distinguished from calcite by its feebler effervescence in cold dilute HCl and from dolomite by its reactions for iron and manganese with the fluxes and by reducing to a black magnetic residue on charcoal.

Remarks. Ankerite is not a widely distributed mineral. It is found in the Western Kentucky fluorite-lead-zinc district. It is also found in the cavities of many limestones in Central Kentucky. It may be formed by the action of carbonated waters upon soluble salts of calcium, magnesium and iron.

47—**Aragonite, calcium carbonate, $CaCO_3$.** Aragonite crystallizes in the orthorhombic system in prismatic forms that are often repeatedly twinned, thereby producing pseudohexagonal forms. It also occurs in forms columnar, stalactitic, reniform, globular, straight or radiating fibers and as incrustations.

Its color is normally white but it may be gray, green, brown, or red. Its streak is white and its luster vitreous. Its hardness is 3.75 and its specific gravity is 2.94. Its cleavage is distinct but not perfect. Its fracture is uneven. Its tenacity brittle. Its diaphaneity transparent to translucent.

Pyrognostics. B. B. aragonite whitens and falls to pieces. The reduced mass reacts alkaline with litmus. When the mineral is moistened with HCl a yellowish red or brick red flame is observed. When the pulverized mineral is boiled with the nitrate of cobalt the product becomes pink. Cold dilute HCl is the solvent.

Differences. Aragonite is distinguished from all other minerals save calcite by effervescing freely in cold dilute HCl and from calcite by a superior hardness, 3.75, by a higher specific gravity 2.94, by falling to pieces when treated before the blowpipe, by turning pink or violet when boiled with $Co(NO_3)_2$, by effervescing in weaker acid than calcite.

Remarks. Aragonite is an unstable form of calcium carbonate. In Kentucky it occurs in the cave deposits of Edmonson and Hart Counties, in fibrous translucent forms.

48—**Fluorite, calcium fluorite, CaF_2.** Fluorite crystallizes in the isometric system, commonly in cubes, but the form may be an octahedron or even a dodecahedron. It may also occur in columnar forms, granular, massive, either coarse or fine, and even compact.

Its color is normally white or greenish but all the primary colors may be found. The sky blue to purple fluorites are among the most beautiful minerals. Its streak is white and its luster vitreous. Its hardness is 4 and its specific gravity 3.12. Its cleavage is perfect and parallel with the face of an octahedron. It therefore has cleavage in four directions. Its fracture is conchoidal. Its tenacity brittle and its diaphaneity transparent to translucent.

Pyrognostics. In the C. T. it decrepitates and phosphoresces. If a matrass is made and the powdered mineral is mixed with $HKSO_4$ and heated HF is evolved which etches the glass. Microcosmic salt mixed with the mineral will also evolve hydrofluoric acid, HF when heated B. B. In the forceps it readily fuses to an enamel that reacts alkaline with litmus. On charcoal it fuses to an enamel and colors the flame yellowish red to brick red. With Na_2CO_3 on charcoal it fuses to a clear bead which becomes opaque upon cooling. When the pulverized mineral is mixed with powdered gypsum and fused, the bead is transparent when hot and opaque when cold. It is decomposed by conc. H_2SO_4 with a rapid evolution of HF which gas is very irritating to the respiratory organs and should not be inhaled.

Differences. Fluorite is readily distinguished from all other fluorides by its perfect octahedral cleavage, by its specific hardness of 4, and by its yellowish red or brick red flame.

Remarks. Fluorite is a widely distributed mineral. It occurs in cubes disseminated through certain limestones and in well defined fissure veins in limestones, sandstones and quartz. Its origin is hydrothermal. In Kentucky it constitutes a very important vein mineral in Crittenden and Livingston Counties in the fluorite-lead-zinc district, and it occurs less abundantly in fissure veins of the inner Bluegrass Region. It finds application as a flux in the treatment of iron ores and is used extensively in the manufacture of glass and white enamels. It comprises one of the important mineral industries of the State. Optical fluorite has been found in the Chinn mine at Mundy's Landing.

49—**Apatite, calcium phosphate—halogens.** $Ca_3(PO_4)_2 + CaF_2$, **or** $CaCl_2$, **or both** in intermediate forms. Apatite crystallizes in the hexagonal system in prismatic forms that may be either long or short, usually terminated by a low pyramid. It may also occur in globular and reniform shapes. It may be massive, and granular or even compact.

The most common colors for apatite are brown and green but white, blue, gray and red shades are known. Its streak is white and its luster is vitreous. Its hardness is 5, and its specific gravity 3.2. Apatite has an imperfect basal cleavage or parting often well developed in microscopic slides. Its fracture is conchoidal. Its tenacity brittle. Its diaphaneity generally translucent, but some white varieties are transparent.

Pyrognostics. B. B. In the forceps apatite fuses with difficulty at 4.75, imparting a yellowish red or brick red color to the flame. If a fragment of the mineral is moistened with conc. H_2SO_4 and then heated the flame is momentarily green from the presence of phosphorus. When mixed with $HKSO_4$ the fluorine bearing varieties will evolve HF which etches the glass. When the mineral is pulverized and mixed with CuO the chlorine bearing varieties will yield a bluish green flame. All varieties when fused with magnesium ribbon on charcoal and the fused mass moistened with H_2O will yield phosphine, PH_3, which is recognized by its offensive odor. Apatite is readily soluble in HCl without effervescence.

Differences. Apatite is readily distinguished from other 6 sided prisms by its definite hardness of 5 and its low pyramidal terminations.

Remarks. Apatite is a common accessory mineral in limestones and their metamorphic derivatives, and in both the acidic and the basic igneous rocks. It also occurs in well-defined mineral veins traversing metamorphic and igneous rocks. In Kentucky it occurs in both the peridotites and the marbles. When it occurs in sufficient quantity it is a valuable fertilizer.

50—**Phosphorite, calcium phosphate containing calcium carbonate and fluoride, $Ca_3(PO_4)_2+CaCO_3+CaF_2$.** This species, if it be worthy of the dignity of a species, must be regarded as a calcium phosphate containing the calcium carbonate molecule. It may be regarded as an impure apatite for its chemical analysis often shows an appreciable percentage of fluorine. In the inner Bluegrass Region of Kentucky it is known as the phosphate rock, where it occurs as an amorphous porous deposit. According to Prof. A. M. Miller, it occurs at the base of the Cuyahoga shale in nodules as spherical as marbles. Also kidney shaped, irregular and of various sizes. It is abundant in the limestone of Central Kentucky. It has been exploited in the Woodburn member of the Upper Trenton and in the top of the Benson bed which is the first terrace beneath the Woodburn. It is regarded as an important economic mineral within the State.

51—**Nitrocalcite, hydrous calcium nitrate, $Ca(NO_3)_2+nH_2O$.** Nitrocalcite occurs in efflorescent silken tufts and masses. It is found in the cave earths. The amount of water is uncertain. It is sometimes given with one molecule of water but the artificial salt carries 4 molecules of water.

The color of the mineral may be either white or gray. Its streak is white. Its taste is sharp and bitter.

Pyrognostics. In the C. T. it yields water and dries out to a pulverulent mass which yields acid red fumes when heated more strongly. B. B. On charcoal it often detonates, slowly fuses and dries out. The salt is very deliquescent before heating but the dried salt is less deliquescent. The color of the flame is yellowish red or brick red. When fused in a matrass with $HKSO_4$ and copper foil it evolves dense brown fumes of the oxides of nitrogen. Its solvent is water.

Differences. It is readily distinguished from niter by the violet flame of KNO_3, and from Chile niter by the persistent yellow flame of $NaNO_3$.

Remarks. Nitrocalcite is found in the cave earths of Kentucky where it is formed by the nitrification of calcium carbonate. The nitric acid is supposed to be derived through the action of nitrifying bacteria upon nitrogenous organic matter derived mainly from the droppings of bats and other cave frequenting animals. It is used in the manufacture of saltpetre and may have been one of the minerals used in the manufacture of gunpowder in the early history of Kentucky. It is in itself a valuable fertilizer.

52—**Perovskite, calcium titanate, CaO, TiO_2.** Perovskite crystallizes in the isometric system, in crystals cubic in habit, but often highly modified. It may also occur as small octahedrons.

Its color is pale yellow, honey yellow, reddish brown or grayish black. Its streak is either white or slightly grayish. The lighter varieties have an adamantine luster but the luster of the darker varieties may be nearly metallic. Its hardness is 5.25 and its specific gravity is 4.01. Its fracture is uneven. Its tenacity brittle and its diaphaneity ranges from transparent to opaque.

Pyrognostics. B. B. In the forceps when moistened with HCl it imparts a yellowish red color to the flame. On charcoal it is infusible. The S.Ph bead in the O. F. is greenish when hot, but becomes colorless upon cooling. In the R. F. the bead is grayish green when hot and violet blue when cold. The solvent for the mineral is boiling H_2SO_4.

Differences. The most distinguishing analytical features of perovskite are its calcium flame and its violet blue S.Ph bead in the reducing flame.

Remarks. Perovskite is a primary mineral found in the peridotites of Crittenden County.

GROUP VI.

Magnesium Mg; Sodium, Na; Potassium, K; Lithium, Li; Ammonium, (NH_4). No group precipitant.

53—**Epsomite, hydrous magnesium sulphate, $MgSO_4,7H_2O$.** Epsomite crystallizes in the orthorhombic system in forms prismatic in habit. It may occur in botryoidal masses and as delicately fibrous crusts. It is often observed as an efflorescence.

Its color and streak are both white and its luster is vitreous. Its hardness is 2.25 and its specific gravity is 1.75. Its cleavage is perfect. Its fracture conchoidal. Its tenacity brittle and its diaphaneity transparent to translucent.

Pyrognostics. In the C. T. it yields much water. The first water evolved reacts neutral with litmus, but at a high temperature the water is acid. It liquifies in a matrass in its own water of crystallization. B. B. In the forceps it fuses easily. On the charcoal it first fuses and then yields an infusible mass which when moistened with the $Co(NO_3)_2$ and reheated assumes a pink color. Its solvent is H_2O. $BaCl_2$ added to this solution gives a heavy white precipitate of $BaSO_4$, insoluble in acids.

Differences. Epsomite is readily distinguished from all other minerals by its extremely bitter taste. One part of the mineral in one million parts of water has afforded to some investigators the bitter taste. It is distinguished from the sulphates of lead, barium, strontium and calcium by its ready solubility in water.

Remarks. Epsomite is always a secondary mineral. It is often a common constituent in mineral waters. In Kentucky it occurs dissolved in certain well and spring waters where it imparts to them a bitter taste. It occurs in the limestone caves in very minute crystals mingled with the cave earth. It has also been observed as a capillary efflorescence upon the surfaces of shale beds, especially where the edges of the shale are exposed. It is not a mineral of economic significance within the State unless the medicinal effect of some of the mineral waters is included.

54—**Magnesite, magnesium carbonate, $MgCO_3$.** Magnesite crystallizes in the rhombohedral division of the hexagonal system but crystals are exceedingly rare. It usually occurs massive and granular, but it may be very compact or even earthy.

Its normal color is white, but it may be yellowish white or even brown. Its streak is white and its luster vitreous, but the finely fibrous varieties are sometimes silky. Its hardness is 4 and its specific gravity is 3.06. Its cleavage is perfect. Its fracture conchoidal. Its tenacity brittle and its diaphaneity translucent to opaque.

Pyrognostics. B. B. In the forceps it is infusible. On charcoal it loses CO_2 and the residue is infusible. If moistened with $Co(NO_3)_2$ and ignited the mass becomes pink. If traces of aluminum are present the mass may be blue rather than pink. Magnesite when pure is not attacked by cold dilute HCl, but often it is feebly attacked perhaps from the presence of $CaCO_3$ molecules. When pulverized it rapidly dissolves in warm dil. HCl with an evolution of CO_2. NH_4OH and Na_2HPO_4 added to the solution, warmed and stirred, precipitates white, crystalline, $MgNH_4PO_4$.

Differences. It differs from calcite and dolomite which minerals it most closely resembles in its superior hardness of 4, in its higher specific gravity of 3.06, in its absence of effervescence in cold dilute HCl and in its flat conchoidal fracture.

Remarks. Magnesite in fine granular masses was found by the author during the summer of 1920 in the glass sand deposits of Tip Top, Hardin County, Kentucky, associated with periclasite.

55—**Periclasite, magnesium oxide, MgO.** Periclase or periclasite crystallizes in the isometric system in cubes and octahedrons. It also occurs in fine granular masses.

Its color and streak are white and its luster vitreous. Its hardness is 5.75 and its specific gravity 3.67. Its cubical cleavage is perfect. Its fracture is uneven. Its tenacity brittle. Its diaphaneity translucent.

Pyrognostics. B. B. Periclasite is unaltered and infusible but the varieties containing manganese darken on charcoal. With $Co(NO_3)_2$ upon prolonged blowing the mass becomes flesh colored. The saturated borax bead when much manganese is present is jet black. The pulverized mineral digested with water reacts alkaline with litmus. The mineral is readily soluble in HCl without effervescence.

Differences. Periclasite is distinguished from magnesite by the absence of effervescence with warm dilute HCl.

Remarks. Periclasite was discovered by the author in the summer of 1920, associated with magnesite in the glass sand deposits of Tip Top, Hardin County, Kentucky.

56—**Spinel, magnesium aluminate, MgO,Al_2O_3.** Spinel crystallized in the isometric system in octahedral forms, very rarely in cubic forms. Twins are common with the plane of the octahedron as the composition face.

Its color is usually some shade of red, but yellow, green, brown and black colors have been observed. Its streak is white and its luster is vitreous. Its hardness is 8 and its specific gravity is 3.78. Its cleavage is imperfect. Its fracture conchoidal. Its tenacity brittle, and its diaphaneity ranges from transparent to subtranslucent.

Pyrognostics. B. B. Without the fluxes spinel is infusible. Ruby spinel changes to brown, then black, and in cooling it becomes green, colorless and finally red. The S.Ph bead is reddish while hot and chrome green when cold. Some varieties will react for iron with fluxes. Spinel when pulverized is slowly decomposed by conc. H_2SO_4. It is dissolved by HCl after fusion with $HKSO_4$.

Differences. Spinel is readily distinguished from all other related minerals by its definite hardness of 8. Topaz has a hardness of 8 but the crystals are orthorhombic and prismatic, rather than isometric.

Remarks. Spinel is a primary accessory mineral in the peridotites of Elliott County in Eastern Kentucky.

57—**Halite, sodium chloride, NaCl.** Halite crystallizes in the isometric system in cubes and octahedrons. The cubical faces are often cavernous. It may occur in columnar forms, also massive, granular to compact.

Its color is white but it is sometimes red, yellow, blue, purple and even black. The streak is white and the luster vitreous. Its hardness is 2.5 and its specific gravity is 2.25. Its cleavage is perfect and cubical. Its fracture is uneven, its tenacity brittle and its diaphaneity transparent.

Pyrognostics. Halite in the C. T. or matrass frequently decrepitates and fuses. B. B. In the forceps it decrepitates and colors the flame an intense and persistent yellow. When a S.Ph bead is saturated with the black oxide of copper, CuO, and halite added, the flame becomes a deep azure blue. Halite is readily soluble in three parts of water. The solution has a strong saline taste. If a few drops of $AgNO_3$ are added to the solution a white, curdy precipitate of AgCl is formed.

Differences. Halite is distinguished from all other minerals by its strong saline taste. Sylvite, KCl, which it most closely resembles in form, yields a violet flame. Its taste is first saline and then bitter.

Remarks. Halite, or common salt, is widely distributed, but not necessarily in large quantities. In Kentucky it occurs in the brines of many wells. It has been obtained by the evaporation of the brines of saline springs and salt licks. In later times by wells drilled in Allen, Clay and Wayne Counties. The output of salt from the State has not been large.

58—**Niter, potassium nitrate, KNO_3.** Niter crystallizes in the orthorhombic system, often in pseudohexagonal, prismatic crystals and in delicately acicular forms. It generally occurs in silky tufts and thin incrustations.

Its color and streak are white and its luster vitreous. Its hardness is 2, and its specific gravity 2.1. Its cleavage is perfect. Its fracture uneven. Its tenacity brittle and its diaphaneity subtransparent.

Pyrognostics. In the C. T. niter melts and volatizes. B. B. In the forceps it deflagrates violently and colors the flame violet, best seen through smalt blue glass. On the charcoal it deflagrates violently throwing out bright scintillations. When mixed with combustible substances and heated it explodes violently. When fused in a matrass with copper foil it evolves dense brown fumes of the oxides of nitrogen. It is readily soluble in water with first a slightly saline and then a pronounced cooling taste.

Differences. Niter is distinguished from all other minerals by its cooling taste and violet flame.

Remarks. Niter is found disseminated through the loose earth on the floors of many caves in the limestone regions of Kentucky, Tennessee and the Mississippi Valley. Also it occurs as crusts on the surface of the cave deposits. During the war of 1812, and also during the Civil War, niter was extracted by leaching from these cave deposits and used in the manufacture of gun powder. The product can find use as a valuable fertilizer, for both the potash and the nitrogen are fertilizing constituents.

The association of sodium with potassium is so intimate that soda niter, $NaNO_3$, should be found in minute quantities in the cave earths of Kentucky, but so far as known to the author it has not yet been reported.

59—**Quartz, silicon dioxide, SiO_2.** Quartz crystallizes in the hexagonal system with trapezohedral tetartohedrism. The crystals are commonly prismatic with the faces horizontally striated and the prisms terminated by one or both rhombohedrons. It frequently occurs in radiating masses with a surface of pyramids or druses. It may be massive and either coarse or fine granular. It may be mammillar, stalactitic or concretionary.

Quartz is normally white or colorless, but all the primary colors may be represented. Its streak is white, even for the black varieties like the blackest of the cairngorm stone and basanite which is the variety known as the Lydian touchstone.

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The luster of the crystallized varieties is wholly vitreous. The hardness is 7 and the specific gravity 2.65. The cleavage is difficult and seldom observed, but it may be cataloged as an imperfect rhombohedral cleavage. The fracture is conchoidal. Most varieties are brittle and transparent but even opaque quartz is known.

Silica, SiO_2, forms 4 distinct types of minerals. (1) The phenocrystalline, crystallized, vitreous type which includes all ordinary vitreous quartz whether it has crystalline faces or not. It is the type included in No. 59. (2) Cryptocrystalline or flint like varieties. These varieties are not crystallized. They are often very compact or made up of layers as in the agate. They are more easily attacked by HF than the members of the first group, and when they occur in layers the layers themselves are attacked with different rapidity. (3) Tridymite, which crystallizes in the hexagonal system in very minute crystals and which is elevated to the dignity of a distinct species. (4) Opal, or hydrated silica but with the amount of water varying widely from 2 to 14 per cent, but usually from 3 to 9 per cent. This variety is soluble in caustic alkalies. It is inferior in hardness and specific gravity to ordinary quartz.

Pyrognostics. B. B. Quartz is infusible. It has been spun into fine threads when fused in the highest heat of an oxyhydrogen flame. It has been fused in a specially constructed electric furnace and fashioned into curved rods or made into plate glass. It is used in utensils for chemical and technical operations. The borax bead is clear and colorless and yields a skeleton of silica. In the S.Ph bead the silica does not dissolve and the fragment of mineral can readily be seen in the clear bead. Fused with sodium carbonate quartz dissolves with effervescence. It is soluble only in hydrofluoric acid. It is only feebly attacked by caustic alkalies.

Differences. Crystallized quartz or the crystalline varieties are readily distinguished from all other minerals by a specific hardness of 7., by a specific gravity of 2.65, by the absence of cleavage planes or the presence of an indistinct rhombohedral cleavage such as may be produced by sudden cooling, by its in-fusibility, by its insolubility in the mineral acids and by the ease with which it cuts glass.

Remarks. Quartz is one of the most widely distributed of all known minerals. It is so abundant that the specific gravity of the first five miles of the earth's crust is taken as the specific gravity of quartz 2.65.

Transparent crystallized quartz occurs in Kentucky lining the cavities of geodes in the Waverlian series. Cairngorm, or smoky quartz is smoky brown or black in color with the dark color due to the presence of some organic compound containing carbon.

Amethyst. A clear purple or bluish violet crystallized quartz found lining the geodetic cavities of the Waverly formation The color is probably due to manganese.

60—**Chalcedony, silicon dioxide, SiO_2.** The cryptocrystalline or chalcedonic varieties of quartz never crystallize. They are flint like, massive and more readily attacked by caustic alkalies than the vitreous varieties. There are many types within the group. Chalcedony itself is either transparent or translucent and has somewhat the luster of wax. It occurs in mammillar, botryoidal and stalactitic forms. In Kentucky chalcedony is found in the geodes of the Waverly formation.

Flint is more opaque than chalcedony and usually of gray, smoky brown and black colors. It breaks with a deep conchoidal fracture and a sharp cutting edge. It was used by the Indians in making their arrows, etc. It occurs in Kentucky in bands and nodules in the limestones and the soils formed by their disintegration.

Chert differs largely from the flint in breaking with a splintery fracture and its colors are generally paler. Much of the material reported as flint is in reality chert.

Agate is a variegated chalcedony. The colors are either banded or in clouds. In the typical agate the bands are irregular, in zigzag lines traversing the mineral mass or in concentric form like a bull's eye.

Onyx. In the onxy the banding consists of straight layers of different colors. The bands may be white and black, or white, brown and black.

61—**Opal, hydrous silicon dioxide, SiO_2,nH_2O.** Opal never crystallizes. It occurs in amorphous forms. It may be massive, or reniform, stalactitic, tuberose or even earthy.

The color is normally white but the same range of colors as appears in quartz may be represented, sometimes the play of colors is very rich. The streak is white and the luster may be vitreous, resinous or pearly. The hardness varies from 5.5 to 6.5 and the specific gravity from 1.9 to 2.3. The fracture is conchoidal, the tenacity brittle and the diaphaneity ranges from transparent to nearly opaque.

Pyrognostics. In the C. T. and O. T. opal yields varying amounts of water. The water content ranges from 2 to 13 per cent in the different varieties. B. B. Opal is infusible but becomes opaque. Yellow varieties that are rich in iron may turn red. It is more readily attacked by HF than either ordinary quartz or the chalcedonic varieties. It is also more soluble in the caustic alkalies but this solubility varies with different varieties.

Differences. Opal is readily distinguished from all other members of the quartz group by its inferior hardness and lower specific gravity.

Remarks. Opaline silica occurs in Kentucky in the siliceous limestones and the argillaceous rocks where it results from the accumulations of, or the accumulation, partial solution and solidification, of the siliceous shells of infusoria, or the spicules of sponges. It is present in nearly all chalcedony, flint and chert.

FELDSPAR GROUP

62—**Orthoclase, $K_2O,Al_2O_3,6SiO_2$.** Orthoclase crystallizes in the monoclinic system in prismatic forms. It may also occur in lamellar forms, massive and granular, and in compact cryptocrystalline or flint like forms.

The flesh red color for orthoclase is the most common but white, yellow, gray and green colors are known. Its streak is always white. Its luster vitreous but on the clinopinacoidal cleavage face it is often pearly. Its hardness is 6.25 and its specific gravity is 2.8. Its cleavage is perfect but usually more distinct parallel to one prismatic face than to the other. Its fracture is conchoidal. Its tenacity brittle and its diaphaneity translucent.

Pyrognostics. B. B. In the forceps it fuses at 5. If moistened with HCl the flame is colored violet which is best seen through blue glass. The variety rich in sodium, like soda orthoclase, fuses more easily and yields the yellow flame of sodium which is absorbed by the blue glass. Orthoclase is insoluble in the mineral acids but readily soluble after fusion with $HKSO_4$.

Differences. Orthoclase is often distinguished from all other minerals by its flesh red color and two cleavages at right angles to each other. The peculiar shade of green in microcline which has the same chemical composition as orthoclase readily distinguishes this species.

Remarks. Orthoclase occurs in small crystals in Kentucky in some of the sandstones of the Big Sandy Valley and in the Cannonsburg quartzite. A petrographic study of the sandstones of the Western coal measures is necessary to prove the absence of orthoclase. If the sample of granite in the museum of the Geological Survey in Frankfort came from Black Mountain, Kentucky, where it is reported to have been found, then orthoclase is present in the State in more than microscopic assemblages.

63—**Albite, $Na_2O,Al_2O_3,6SiO_2$.** Albite crystallizes in the monoclinic system in prismatic forms, often showing fine striations due to polysynthetic twinning. It may also occur in tabular forms, lamellar, massive and granular.

Its color as its name implies is normally white, but bluish, grayish and reddish varieties are known. Its streak is white. Its luster vitreous, but on a cleavage surface it is somewhat pearly. Its hardness is 6.25 and its specific gravity is 2.64. Its fracture is uneven. Its tenacity brittle. Its diaphaneity ranges from transparent to subtranslucent.

Pyrognostics. B. B. Albite fuses at 4 to a colorless or white glass imparting an intense and persistent yellow coloration to the flame. Albite is insoluble in the mineral acids but is readily soluble after fusion with $HKSO_4$.

Differences. Albite is readily distinguished from the other feldspars by its white color, often by its tabular form, from oligoclase which gives a yellowish red flame from its calcium content, and has a fusion point of 3.5, from orthoclase by a cleavage angle of 90 for orthoclase and less or more than 90 for albite and from barite by its specific gravity of 4.6.

Remarks. Albite so far as known to the author occurs in Kentucky only in the arkosic sandstones of the Eastern Coal Measures where it occurs in small microscopic crystals. It is reported to have been found in the Elliott County dikes in Eastern Kentucky.

PYROXENE GROUP

64—**Enstatite, MgO,SiO_2.** Enstatite crystallizes in the orthorhombic system with prismatic habit, but distinct crystals are rare. It usually occurs massive, fibrous or lamellar.

Its color is grayish white or yellowish white. The ferriferous variety bronzite is grayish green, olive green or brown in color. The streak of enstatite is white or slightly grayish and the luster of enstatite when nearly free from iron vitreous but when iron is present in sufficient amount for bronzite the luster is metalloidal. The hardness of enstatite is 5.5 and the gravity is 3.2. The cleavage is perfect or nearly so with two prismatic cleavages intersecting at angles of approximately 87 and 93 degrees. The fracture is uneven. The tenacity is brittle and the diaphaneity is translucent or subtranslucent.

Pyrognostics. B. B. Enstantite is very refractory. It fuses at 6 in von Kobell's scale of fusibility, that is it is rounded on the thin edges of very fine splinters by prolonged blowing. It is insoluble in HCl but readily soluble after fusion with $HKSO_4$ from which Na_2HPO_4 precipitates from alkaline solutions white crystalline precipitate of $MgNH_4PO_4$.

Differences. Enstatite is distinguished from all other minerals save pyroxenes by its cleavage angles of 87 and 93 degrees, and from other pyroxenes by its gray to brown color, often lamellar structure, and often by its bronze-like luster.

Remarks. Enstatite occurs in Kentucky in the Elliott County peridotites and should occur in the peridotites of Crittenden and Livingston Counties.

65—**Augite.** The chemical composition of augite is chiefly $CaO,MgO,2SiO_2$, with (Mg,Fe), $(Al,Fe)_2$, SiO_4. It occasionally contains some of the alkalies and frequently titanium.

Augite crystallizes in the monoclinic system in short, straight prismatic forms. It frequently consists of granular aggregates and may be fibrous.

Its color is greenish black, or brownish black or black. Its streak is white and its luster vitreous. Its hardness is 5.75 and its gravity is 3.4. Its cleavage in two directions is perfect or nearly so at angles of 87 and 93 degrees. Its fracture uneven. Its tenacity brittle. Its diaphaneity opaque but may be translucent in thin crystals.

Differences. Augite is readily distinguished from hornblende which it most closely resembles, by the cleavage angles 87 and 93 degrees while hornblende has cleavages of 56 and 124 degrees. Also it is distinguished from other pyrozenes by its greenish black color. Hypersthene which it somewhat resembles is darker in color and richer in ferric iron.

Remarks. Augite alters by paramorphism into hornblende. It occurs in Kentucky in the peridotites of Caldwell, Crittenden and Lyon Counties.

Garnet Group

66—**Almandite, $3FeO,Al_2O_3,3SiO_2$.** Almandite is the precious or Oriental garnet and also the common garnet. It crystallizes in the isometric system in regular rhombic dodecahedrons.

Its normal color is red but may be brown or black. Its streak is white and its luster vitreous. Its hardness is 7. and its specific gravity is 4.1. The specific gravity of the garnet varies from 3.15 to 4.3. The cleavage is sometimes rather distinct but usually wanting. The fracture is conchoidal. The tenacity brittle but compact varieties may be tough. The diaphaneity ranges from transparent to subtranslucent.

Pyrognostics. Almandite fuses at 3 to a light brown or black glass. The borax bead is bottle green in the reducing flame. Almandite is only partially decomposed by HCl but is readily decomposed by fusion with Na_2CO_3. This product is readily soluble in HCl. When this solution is boiled with a little HNO_3 to oxidize ferrous iron to ferric and NH_4OH added a precipitate is obtained consisting of $Fe_2(OH)_6$ and $Al_2(OH)_6$.

Differences. Almandite is distinguished from other isometric minerals by its hardness of 7 and its red color.

Remarks. Almandite occurs in small crystals in the peridotites of Eastern Kentucky.

67—**Pyrope, $3MgO,Al_2O_3,3SiO_2$.** Pyrope crystallizes also in rhombic dodecahedrons of the isometric system but the crystals are very small.

Its color is red and the crystals have sometimes been mistaken for the ruby which is now the highest priced jewel per carat. The streak is white and the luster vitreous. Its hardness is 7, and its specific gravity is 3.73. Its cleavage is wanting. Its fracture conchoidal. Its tenacity brittle. Its diaphaneity transparent.

Pyrognostics. B. B. Pyrope fuses at 3.5 to a light colored glass. After fusion with Na_2CO_3 it readily passes into solution with HCl and from this solution NH_4OH precipitates the aluminum as $Al_2(OH)_6$ and Na_2HPO_4 precipitates the magnesium as Mg,NH_4PO_4.

Differences. Pyrope is distinguished from the other garnets by its fusion at 3.5, its red color and its normal occurrence in very small rhombic dodecahedrons.

Remarks. Pyrope occurs in the peridotite of Elliott County, Kentucky, and by the similarity of the dikes it should occur in other peridotites of Eastern Kentucky reported by J. S. Hudnall, Assistant Geologist of Kentucky.

OLIVINE GROUP

68—**Olivine, $2(Mg.Fe)O,SiO_2$.** Olivine crystallizes in orthorhombic system in crystals sometimes flattened but with edges and angles rounded as if by solution. It most commonly occurs in embedded grains but may occur massive and granular and even compact.

Olivine is usually olive green in color, whence its name, but it may be grayish green or even brownish. Its streak is white and its luster vitreous. Its hardness is 6.75 and its specific gravity is 3.32. Its cleavage is distinct but not perfect. Its fracture is conchoidal. Its tenacity brittle. Its diaphaneity transparent to translucent.

Pyrognostics. Olivine before the blowpipe is generally infusible but the varieties that are richest in iron will fuse to a magnetic globule. The borax bead in all cases in the R. F. will be bottle green. If manganese is present in appreciable quantity the borax bead when thoroughly saturated will be jet black. Olivine is soluble in both HCl and H_2SO_4 with a separation of gelatinous silica.

Differences. Olivine is readily distinguished from other minerals by its olive green color and by its occurrence in rounded grains or masses.

Remarks. Olivine occurs in the peridotites of Western Kentucky but it is now almost entirely altered to serpentine.

ZIRCON GROUP

69—**Zircon, ZrO_2,SiO_2.** Zircon crystallizes in the tetragonal system in short but well defined four sided prisms terminated by a four sided pyramid at either extremity. It may also occur in irregular forms and in grains.

Its color may be brownish yellow, reddish brown, yellowish green or even colorless. Its streak is white and its luster admantine. Its hardness is 7.5 and is specific gravity 4.68. Its cleavage is imperfect. Its fracture conchoidal. Its diaphaneity ranges from transparent to opaque.

Pyrognostics. B. B. Zircon alone is infusible. The colorless varieties are unaltered, the red varieties become colorless, the dark colored varieties become white, and some varieties glow and increase in density. Zircon is not perceptibly acted upon by S.Ph. With Na_2CO_3 in the loop of a Pt wire it is rendered soluble. When fused with Na_2CO_3 or $HKSO_4$ the fused mass dissolves in HCl and this solution turns tumeric paper orange red. The mineral is insoluble in HCl but when pulverized it slowly dissolves in conc. H_2SO_4.

Differences. Zircon is readily distinguished by its four sided prisms terminated by a four sided pyramid at either extremity and by its solution turning tumeric paper orange red. It is distinguished from thorite which it resembles in form by its hardness of 7.5 for thorite is only 4.75 in hardness.

Remarks. Zircon occurs in Kentucky in small microscopic crystals in the sandstones and quartzites of the Eastern Coal Measures.

EPIDOTE GROUP

70—**Epidote, $H_2O,4CaO,3(Al,Fe)_2O_3,6SiO_2$.** Epidote crystallizes in the monoclinic system in prismatic forms. It may also occur in fibrous forms that may be either divergent or parallel. It may be massive and granular, and often occurs as small grains in metamorphic rocks.

Its color is pistachio green which may be called epidote green for this peculiar shade of color is seldom found in any other mineral. The mineral may be greenish black or even black in color. The streak is white or slightly grayish and the luster is vitreous. Its hardness is 6.75 and its specific gravity is 3.4. Its cleavage is perfect. Its fracture uneven. Its diaphaneity ranges from transparent to opaque.

Pyrognostics. In the C. T. and O. T. it yields water upon strong ignition. In the forceps it fuses at 3.5 coloring the flame yellowish red. On charcoal it fuses to a dark brown to black magnetic mass. The borax bead in the R. F. is bottle green but the manganiferous varieties when thoroughly saturated yield a jet black bead in the O. F. It is readily decomposed by Na_2CO_3. Before ignition it is only partially dissolved by HCl, but after ignition it passes into solution with a separation of gelatinous silica.

Differences. Epidote is easily distinguished by its pistachio green color and yellowish red flame.

Remarks. Epidote is usually formed by the interaction of the plagioclase feldspars and the ferromagnesium minerals. Grains of epidote have been found in microscopic slides in the sandstones and quartzites of the Eastern Coal Measures.

MICA FAMILY

71—**Muscovite, $2H_2O,K_2O,3Al_2O_3,6SiO_2$.** Muscovite crystallizes in the monoclinic system in crystals that are tabular in habit. The plates may be very large as in Groton, N. H., or in very small aggregates that may be stellate, plumose or even globular.

The color is normally white or colorless, hence the common name white mica, but grayish, brownish and greenish varieties are known. Its streak is white and its luster is vitreous. The fine scaly or fibrous variety sericite has a silky luster. Its cleavage is in only one direction, basal, and in muscovite cleavage reaches its highest degree of perfection. Its hardness is 2.25 and its specific gravity is 2.8. Its fracture is hackly. Its tenacity flexible, elastic and tough. Its diaphaneity is transparent especially in thin sheets.

Pyrognostics. In the C. T. muscovite yields water, which with brazil wood may react for fluorine. If thin sheets of muscovite are held in the forceps in the flame of the Bunsen burner the mineral whitens in concentric layers and becomes brittle. The flame is violet showing the presence of potassium. On the charcoal muscovite fuses at 5.7 to a gray or yellowish glass. The iron bearing varieties yield a bottle green bead with borax in the R. F. and the chromium varieties an emerald green bead.

Muscovite is decomposed by fusion with Na_2CO_3. It is insoluble in the mineral acids.

Differences. Muscovite is distinguished from all other minerals save the micas by its eminent basal cleavage. It is separable by mechanical means into sheets or plates one-thousandth of a millimeter in thickness. It is distinguished from the other micas by its white or brownish color and violet flame.

Remarks. Muscovite is known as the white mica and as the potassium mica. It is the commonest of the micas and occurs in white scales and plates in the arkosic sandstones and quartzites of the Eastern Coal Measures and in the sandstones of the northeastern part of the State.

72—**Biotite, $(H,K)_2(Fe,Mg)_2AlSi_3O_{12}$.** This formula is often used to express typical biotite but ferric iron is often present replacing the aluminum in amounts ranging from one to 20 per cent. Biotite crystallizes in the monoclinic system in tabular or short prismatic habit. It also occurs in spheroidal aggregates of scales of biotite with a few quartz grains as in the orbicular granite of Craftsbury, Vt., or more commonly in scales or plates disseminated throughout both sedimentary and metamorphic rocks. It is the ferromagnesian mineral of the biotite granites that are of so great value in constructional and monumental work.

Its color is normally black, often a deep black in thick crystals. It may be brownish black or greenish black in color. Its streak is white and its luster is splendent on the cleavage plane and the masses of plates themselves may have a submetallic luster. Its hardness is 2.75 and its specific gravity is 2.9. If the iron content becomes abnormally high as in the variety lepidomelane from Litchfield, Me., the specific gravity exceeds 3. Its cleavage is highly perfect. Its fracture is hackly. Its tenacity flexible, and its diaphaneity ranges from transparent to opaque. The thin sheets are normally perfectly transparent.

Pyrognostics. In the C. T. it yields water less abundantly than muscovite. In the O. T. many varieties react for F. With borax in the R. F. the bead is bottle green. In the forceps it whitens on the thin edges tinging the flame violet. On charcoal it whitens and fuses with prolonged blowing. It is decomposed by $HKSO_4$. It is insoluble in HCl but slowly decomposes by conc. H_2SO_4 with a separation of scaly silica.

Differences. Biotite is readily distinguished from all minerals save micas by its highly perfect basal cleavage and from other micas by its black or brownish black color and splendent luster on its cleavage surfaces. The sheen on biotite cleavage faces readily distinguishes it from hornblende, which is black or greenish black and has cleavage in two directions instead of one.

Remarks. Biotite is a widely distributed mineral in the igneous, sedimentary and metamorphic rocks. It is common in the micaceous sandstones of Kentucky and in the peridotites of the Eastern Coal Measures. This mica is known as the black mica, and also as the iron mica.

73—**Phlogopite, $R_3Mg_3Al(SiO_4)_3$.** According to F. W. Clarke the above formula represents typical phlogopite but there is considerable variation in the chemical composition of the different phlogopites.

Phlogopite crystallizes in the monoclinic system, usually in oblong, six sided prisms, with irregular sides and often tapering. The crystals may be large and coarse.

The normal color is amber with a copper like reflection. It may be green, brownish yellow, or even colorless. Its streak is white and its luster is pearly on perfect cleavage faces. Its hardness is 2.75 and its specific gravity is 2.8. Its cleavage is basal and highly perfect. Its fracture is hackly. Its tenacity is flexible for the thin laminae are tough and elastic. Its diaphaneity is transparent in thin sheets and the color of the product viewed is amber.

Pyrognostics. In the C. T. phlogopite yields water at a high temperature. In the O. T. it usually reacts for fluorine. In the forceps it whitens on the thin edges. On charcoal it whitens and slowly fuses. With borax some varieties yield a bottle green bead in the R. F. It is insoluble in HCl but completely decomposed by conc. H_2SO_4 with a separation of thin scales of silica.

Differences. Phlogopite is distinguished from all other micas by its amber color and its large magnesium content. The asterism of phlogopite when a candle flame is viewed through a thin sheet is characteristic of the mineral.

Remarks. Phlogopite is known as the amber mica and as the magnesium mica. It has been considered by most mineralogists as of secondary origin associated especially with limestones, dolomites and marbles but Prof. L. W. Currier of Syracuse University has found phlogopite of primary igneous origin in the peridotites of Western Kentucky.

74—**Chlorite.** The chlorite division of the mica group takes its name from the fact that a large number of the species included in these brittle mica are green in color which is characteristic of minerals rich in ferrous iron. The chlorites are hydrous silicates of aluminum with ferrous iron and magnesium. They are all of secondary origin resulting from the alteration of augite, hornblende, biotite, garnet, etc. They occur as small monoclinic tabular crystals or plates in most cases and often made of large masses of rocks consisting essentially of chlorite and a little quartz. Sometimes quartz is absent and there is little else than scales of chlorite.

The color is some shade of green often a dark green. The streak is uncolored. The luster somewhat pearly. The tenacity is brittle but some of the chlorite group like clinochlore when the thin folia are bent retain that position, unlike the flexible micas. The hardness varies from 1 to 2 and the specific gravity from 2.7 to 2.9. The cleavage is perfect. The diaphaneity is transparent in extremely thin plates or scales and in thicker masses opaque.

Pyrognostics. In the C. T. all chlorites yield water. In the O. T. they all yield water. In the forceps they are difficultly fusible on the thin edges but many of them whiten. On charcoal they fuse with difficulty to a grayish black or black glass which is sometimes magnetic. Also some varieties exfoliate somewhat. All varieties with borax give a bottle green bead in the R. F. They are only partially decomposed by HCl, but completely decomposed by conc. H_2SO_4.

Differences. The chlorites are distinguished from all minerals save those of the mica family by their perfect basal cleavage into extremely thin plates or sheets and from the flexible micas by their brittleness of the chlorite scales and their green color.

Remarks. Scales and threads or fibers of chlorite occur in the sandstones and quartzites of Eastern Kentucky where they are probably derived from the alteration of biotite. It occurs also in the Crittenden County peridotite, probably derived from a pyroxene. It may be expected that chlorite will be found in microscopic scales in many of the greenish tinted rocks of sedimentary origin, when these rocks are studied petrographically.

SERPENTINE GROUP

75—**Serpentine, $2H_2O,3MgO,2SiO_2$.** Serpentine is a hydrous silicate of magnesium that crystallizes in the monoclinic system, in distinct crystals but only as a pseudomorph. Its usual occurrence is in massive forms that may be fine granular to cryptocrystalline. Microscopically massive serpentine often shows it to be finely fibrous or felted. It often occurs in most delicate silky fibers so fine that according to a report from the laboratory of the U. S. Geological Survey a single pound of the fiber would spin into a thread 32,000 feet in length. The fibres are usually flexible.

The color of serpentine is some shade of green, and even the darkest serpentines are greenish black rather than black. The streak is white, but sometimes shining. The luster is usually feeble but pearly, resinous, etc., while in the delicately fibrous variety chrysotile it becomes silky. Its hardness varies from 2.5 to 4 and its specific gravity is 2.6. Its cleavage is distinct. Its fracture conchoidal. Its tenacity tough to brittle, the delicate fibers are flexible and usually tough. The diaphaneity ranges from translucent to opaque.

Pyrognostics. In the C. T. all varieties of serpentine yield water. In the forceps it fuses at 6 which is almost infusible. The borax bead usually becomes bottle green in the R. F. showing the presence of iron. It is decomposed by fusion with Na_2CO_3. Decomposed by HCl and by H_2SO_4. In the case of chrysolite and conc. H_2SO_4 the silica is left as very fine threads.

Differences. Serpentine is distinguished from other minerals by its green color, and massiveness. The fibrous varieties by their green color and toughness. This factor usually distinguishes it from the fibrous amphiboles.

Remarks. Serpentine is seldom, if ever, of primary origin, but normally it is a secondary mineral derived from the alteration of basic igneous rocks. Olivine is particularly prone to yield serpentine by the loss of the iron as magnetite and the hydration of the magnesium silicate that remains. Serpentine occurs in the peridotites of Western Kentucky where it is derived from olivine.

TALC GROUP

76—**Talc, $H_2O,3MgO,4SiO_2$.** According to some authors talc crystallizes in the orthorhombic system and according to others in the monoclinic system. The crystals are tabular or scaly in habit but indistinctly developed. It may be massive with a foliated structure, globular or stellated. It may also occur massive and granular, either coarse or fine.

Its color is white, silvery white, apple green, grayish green, and even a very dark green. Its streak is white but the very dark green varieties may give a greenish streak. Its luster is pearly on the cleavage face but otherwise vitreous. Its hardness is 1 and its specific gravity is 2.75. Its cleavage is basal and perfect. Its fracture uneven. Its tenacity in masses brittle but the thin laminae are flexible and inelastic. Its diaphaneity is translucent.

Pyrognostics. In the C. T. talc yields water at a high temperature. In the forceps fuses with great difficulty on the thin edges. On charcoal it whitens, exfoliates, and fuses on the edges. The fused mass moistened with the nitrate of cobalt and reheated assumes a pink or pale red color. The S.Ph bead shows a skeleton of silica. It is decomposed upon fusion with $HKSO_4$. Talc is insoluble in the mineral acids. Rensselaerite is the only variety of talc that is decomposed by conc. H_2SO_4.

Differences. Talc is readily distinguished from other minerals by its hardness of 1 to 1.5. It is inferior in hardness to serpentine and when pure talc is gritless when ground between the teeth. Its decided soapy or greasy feel is distinctive.

Remarks. Talc in the massive form is known as steatite which is commonly called soapstone. This is the variety of Nelson County, Virginia. French chalk is a fine granular variety that marks cloth easily. Foliated talc occurs in easily separable inelastic plates and scales and is the variety that forms the base of nearly 100 products on the American market.

Talc is always of secondary origin derived from the metamorphism of nonaluminous amphiboles, pyroxenes, olivine and garnet. The alteration of the pyroxenes in the peridotites of both Eastern and Western Kentucky could produce some talc.

GLAUCONITE DIVISION

77—**Glauconite.** Glauconite is essentially a hydrous silicate of iron and potassium. The material regarded as glauconite is usually a mixture and therefore the composition varies widely. The mineral is amorphous and earthy but may occur in loosely granular masses.

Its color is some shade of green and its occurrence so often in fine granules has led to the common name for it of greensand marl. Its streak is colorless or greenish but lighter in color than the grains themselves. Its luster is earthy or dull. Its hardness is 2 and its gravity is 2.3. Its tenacity is brittle and the grains are opaque.

Pyrognostics. In the O. T. glauconite yields much water. In the forceps it fuses easily coloring the flame violet from the potassium which is best seen through smalt blue glass. On the charcoal it fuses easily to a black, magnetic mass. The borax bead is bottle green in the R. F. The S.Ph bead shows a skeleton of silica. Some varieties are decomposed by HCl while others are seemingly unattacked. All varieties are soluble in HCl after fusion with Na_2CO_3.

Differences. Glauconite resembles earthy chlorite more strongly than any other mineral but the chlorites do not contain the alkalies and therefore the violet flame of the potassium is distinctive.

Remarks. Glauconite is always of secondary origin and is found more often in the sandstones and shales than in the limestones. It has often been observed in Kentucky in the various shale formations. If it could be found in sufficient quantities it would make a valuable fertilizer.

KAOLINITE DIVISION

78—**Kaolinite, $2H_2O,Al_2O_3,2SiO_2$.** Kaolinite crystallizes in the monoclinic system in thin rhombic or hexagonal plates or scales. It usually occurs as a clay-like mass that may be compact, friable or mealy. It is regarded as the basis of nearly all clays.

Its color when pure is white, but it may be yellowish, brownish, bluish, grayish or reddish. Its streak is white for the plates or scales and its luster pearly on the cleavage planes of the scales or plates, but the luster of the massive forms is often earthy. Its hardness is 2.25 and its specific gravity 2.62. Its cleavage is basal and perfect. In tenacity the tabular plates are flexible and inelastic but the massive variety is friable.

The diaphaneity of the thin scales is transparent and the scale aggregates are translucent.

Pyrognostics. In the C. T. it yields water readily. In the forceps it is infusible. On charcoal it is infusible but the strongly ignited mass when moistened with $Co(NO_3)_2$ and reheated becomes a deep blue. It is decomposed by fusion with $HKSO_4$. It is insoluble in dilute mineral acids, but decomposed by boiling conc. H_2SO_4 into aluminum sulphate and free silica.

Differences. Kaolinite most closely resembles chalk when in the massive form, Kaolinite as noted above is insoluble in HCl while chalk, $CaCO_3$, dissolves with rapid effervescence in cold dilute HCl. Furthermore chalk is gritty and harsh when rubbed with the fingers while kaolinite is smooth and unctuous. Chalk is non-plastic while kaolinite usually contains enough impurities to render it plastic.

In Kentucky it occurs as a constituent in nearly all, if not all clays. Its best development is in the Jackson Purchase. The high grade fire clays of Carter County closely approximate kaolinite. It is an important economic factor in the State.

79—**Halloysite. $2H_2O,Al_2O_3,2SiO_2+Ag$.** Halloysite has no crystal system or crystal form. It occurs massive, clay-like or earthy.

Its color is white, yellowish white, grayish, greenish, bluish or reddish. Its streak is white and its luster may be pearly, waxy or earthy. Its hardness is 1.5. Its specific gravity is 2.1. Its fracture is conchoidal to uneven. Its tenacity brittle. Its diaphaneity ranges from translucent to opaque.

Pyrognostics. In the C. T. halloysite yields much water. A part of the water is liberated at temperatures below 250 degrees but a part is liberated only at temperatures exceeding 400 degrees. In the forceps it is infusible. On the charcoal it is infusible but the strongly ignited mass assumes a deep blue when moistened with $Co(NO_3)_2$ and reheated. The S.Ph bead shows a skeleton of silica. Halloysite is soluble in the mineral acids from which solution NH_4OH precipitates white gelatinous $Al_2(OH)_6$.

Differences. Halloysite is readily distinguished from kaolinite by its solubility in HCl and in yielding a part of its water only at temperatures exceeding 400 degrees. It also differs in its conchoidal fracture. It is non-plastic.

Remarks. Halloysite is associated with the clays that are so widely distributed over the State of Kentucky and so far as known no attempt has been made to distinguish it from kaolinite. It is also associated with the iron ores and manganese minerals in Kentucky.

TITANO-SILICATE GROUP

80—**Titanite, CaO,TiO_2.** Titanite crystallizes in the monoclinic system in crystals much varied in habit but often wedge-shaped or flattened. It may also occur in massive, compact and lamellar forms.

Its color shades from brown to black. Its streak is white and its luster ranges from adamantine to resinous. Its hardness is 5.25 and its specific gravity is 3.5. Its cleavage is distinct but there is often a parting plane in titanite that is more highly developed than the cleavage due to twinning laminae. Its fracture is uneven. Its tenacity is brittle, and its diaphaneity ranges from transparent to opaque.

Pyrognostics. B. B. In the forceps titanite fuses at 3 with intumescence to a yellow brown or black glass. On the charcoal it fuses with intumescence and becomes yellow, brown or black. Fused with borax the mass becomes yellowish green. The S.Ph bead in the R. F. is violet. Varieties rich in iron should be fused with a flux and tin on charcoal. The pulverized mineral is partially decomposed by conc. HCl. If this solution is boiled with granulated tin it assumes a violet color. It is soluble in conc. H_2SO_4 and in HF.

Differences. Titanite is often distinguished from other titanium bearing minerals by the wedge-shaped character of its crystals. It is distinguished from all minerals not titaniferous by its violet S.Ph bead.

Remarks. Titanite is a very common accessory microscopic constituent of igneous rocks. In Kentucky its home is in the western peridotites.

INDETERMINATE

81—**Green Shale.** This shale denoted by W. A. Nelson a bentonite is introduced here because its analytical reactions and chemical composition have not yet been received from Washington. It occurs in colloidal form.

In its physical properties it is white or yellowish white or greenish. Its streak is white and its luster earthy. Its hardness is between 1 and 2 and its gravity between 2 and 3. Its tenacity is brittle and its diaphaneity translucent to opaque.

Pyrognostics. In the C. T. it yields water. In the forceps infusible. On charcoal infusible, but the strongly ignited mass moistened with $Co(NO_3)$ and reheated becomes blue.

Differences. Comparison should here be made with kaolinite and halloysite. Unlike these minerals bentonite when immersed in water rapidly absorbs moisture and increases notably in volume.

Remarks. Bentonite is supposed to be a volcanic ash of rhyolitic type. The green shale, so called in Kentucky, is found along the Kentucky River from Frankfort to Camp Nelson. Its status is questionable.

SALTS IN SOLUTION

According to the numerous analyses of the mineral waters of Kentucky as made in the laboratories of the Kentucky Geological Survey and of the Kentucky Experiment Station, Lexington, Kentucky, there are several salts in solution in the underground waters of the State. Some of these may occur as natural minerals in the deeper buried strata but their occurrence at the surface has not yet been proved. They are therefore classified as salts in solution rather than as definite minerals. Many of the salts reported in mineral waters do occur as natural minerals within the State and are therefore described in Chapters VI. and VII. The purpose here is simply to list those salts that occur in solution within the Commonwealth of Kentucky and have not yet been proved to exist as actual minerals within the State.

In the various reports of the Kentucky Geological Survey the author has found the following salts in solution, none of which are described as minerals in either Chapter VI. or VII.

Sulphide of iron, Mercer County.
Manganese carbonate, Bath County.
Barium carbonate, Bath County.
Barium chloride, Clay and Meade Counties.
Calcium chloride, Wayne County.
Magnesium chloride, Bath, Fayette, Hardin and Warren Counties.
Manganese sulphate.
Sodium carbonate, Fayette and Warren Counties.
Sodium sulphate, Bath, Daviess, Ohio and Warren Counties.
Sodium sulphide, Bath County.
Sodium bromide, Bath, Mercer, Nicholas and Woodford Counties.
Sodium iodide, Bath, Mercer, Nicholas and Woodford Counties.
Sodium biborate, Bath, Nicholas and Woodford Counties.
Strontium chloride, Clay and Meade Counties.
Potassium sulphate, Fayette, Marion, Mercer, Ohio, Whitley and Woodford Counties.
Potassium chloride, Bath, Fulton, Marion, Warren and Wayne Counties.
Lithium carbonate, Woodford County.
Lithium chloride, Bath and Nicholas Counties.

CHAPTER VIII.

THE MINERALLOIDS

Strictly speaking the products treated in this chapter are not minerals. They are, however, mineral-like compounds worthy of recognition and description. They are always included in the various volumes of the Mineral Resources of the United States and the Mineral Industry, its Statistics, Technology and Trade. They are also treated in the appendix of the larger text books of mineralogy. Some authors will choose to eliminate them because various processes of life have played some part in their derivation. Others will eliminate them because they do not all crystallize with definite geometrical forms, but all minerals do not crystallize. Others may seek to include some of them with the minerals because they do crystallize in definite form and possess all the characteristic physical and chemical properties of minerals. To avoid any possibility of criticism for an error of either omission or commission it has seemed wise to the author to include these organic products in the chapter entitled, "The Mineralloids." Many of them are mineral-like in their properties and possess fairly definite chemical composition.

The mineralloids fall into four distinct groups as follows:

1—The salts of organic acids.
2—The hydrocarbons.
3—The oxygenated hydrocarbons.
4—The coals.

Salts of Organic Acids

Three salts of oxalic acid occur in nature in well defined species as whewellite, calcium oxalate, oxammite, ammonium oxalate and humboldtine, iron oxalate. The calcium oxalate is the most common for oxalic acid is easily formed from cellulose and it is therefore surprising that whewellite has not been found in the coal deposits of Kentucky. The one salt of an organic acid that is definitely known to occur in Kentucky is mellite which is the aluminum salt of mellitic acid.

82—**Mellite, $Al_2C_{12}O_{12},18H_2O$.** Mellite crystallizes in the tetragonal system in square pyramids. It may also occur in nodular forms, massive and granular.

Its color is normally a honey yellow but it may be white or even reddish brown. Its streak is white and its luster is resinous in the honey yellow varieties and vitreous in the white varieties. Its hardness is 2.25 and its specific gravity is 1.6. Its cleavage is imperfect. Its fracture conchoidal. Its tenacity brittle and its diaphaneity transparent to translucent.

Pyrognostics. In the C. T. mellite yields much water. In the candle flame it whitens but does not burn. In the forceps it loses water, and CO which burns with a blue flame. On charcoal it is slowly converted into the oxide after which its reactions are characteristic of alumina. Ignited on charcoal and moistened with the nitrate of cobalt and reheated the assay becomes blue. It dissolves in boiling water and in the mineral acids.

Differences. It is distinguished from all other minerals known to occur in Kentucky by its reactions for oxalic acid as given above.

Remarks. Mellite is found sparingly in association with some of the coal measures of Kentucky. It is important as showing the range and variety of the reactions that take place in the formation of coal.

THE HYDROCARBONS

F. W. Clarke states in his Data of Geochemistry that "natural gas, petroleum, bitumen and asphaltum are all essentially compounds of carbon and hydrogen, or more precisely mixtures of such compounds in bewildering variety." The hydrocarbons proper which include the various kinds of mineral wax and mineral tallow are essentially members of the paraffine series, C_nH_{2n+2}.

The hydrocarbons naturally divide themselves into:
The paraffines, C_nH_{2n+2}
The olefines, C_nH_{2n}
The acetylenes, C_nH_{2n-2}

The turpentines, C_nH_{2n-4}
The benzenes, C_nH_{2n-6}
Also series C_nH_{2n-8}
C_nH_{2n-10}
$C_{35}H_{22}$

Members of the first 8 series have been found in petroleum.

Of the paraffine series C_nH_{2n+2} the first four members are gaseous and are known as methane, ethane, propane, butane. From five to sixteen inclusive the paraffines are liquid and from seventeen on semi-solids and solids.

83—**Methane. Natural gas, CH_4.** This product is the first member of the paraffine series but with it occur other members of the paraffine series in quite subordinate amounts.

Pyrognostics. Marsh gas, CH_4, burns with an intense heat and a blue smokeless flame.

Remarks. Natural gas has been produced in a large number of counties in Kentucky and constitutes a very important economic product.

84—**Petroleum.** Chemically considered petroleum consists for the most part of various members of the paraffine series, C_nH_{2n+2}. It falls within the liquid division between C_4H_{10}, the last of the gases, and $C_{17}H_{36}$, the first of the semisolids or solids, but sometimes members of the olefine series, C_nH_{2n}, are of equal importance to the paraffines in the composition of petroleum. Various members of other series than the paraffines and its olefines may also be present. The Caucasian petroleum carries members of the benzene series.

Petroleum is a liquid with unpleasant odor and of usually dark yellowish green color, but there is a wide variation in the color. The specific gravity also varies according to the percentage of the lower hydrocarbons present in a given oil.

Pyrognostics. Petroleum burns easily with a luminous sooty flame. In a matrass when carefully evaporated it leaves a residue of the heavier hydrocarbons.

Differences. Petroleum is readily distinguished from all other liquid mineralloids by its yellowish green color and obnoxious odor.

Remarks. Many theories have been advanced to account for the origin and accumulation of petroleum. The theories thus far advanced may be divided into the inorganic and the organic. D. Mendelief considered the existence of iron carbides within the earth to which percolating waters gain access and generate hydrocarbons. If such carbides exist at reasonable depths then the suggested reaction might take place.

It is now generally recognized that petroleum may be derived from either animal remains or from plant tissues or from both. There is abundant experimental evidence to confirm this view.

The oil fields of Kentucky are widely distributed. Oil occurs in most of the 120 counties of the state and forms one of her most important economic mineral products.

85—**Asphalt,** $\mathbf{C_nH_{2n+2}}$. Essentially asphalt or mineral pitch is a mixture of different hydrocarbons but a part of them may be oxygenated. It therefore belongs in the group of the solid hydrocarbons of the paraffine series. The pasty viscid varieties are called malthas. When asphalt fills the pore spaces in sandstones, limestones and sometimes shales the product is known as asphaltic rock or rock asphalt.

In color asphalt is brown or black. Its streak closely resembles the sample tested but a little lighter in color. The luster is resinous or pitchy. Its hardness varies with the amount of evaporation of volatile hydrocarbons that have been removed. When thoroughly dried out its gravity is 1.4. When dried the compact form breaks with a conchoidal fracture. It is brittle and opaque. Its odor is bituminous.

Pyrognostics. In a matrass asphalt melts at a temperature between 90 and 100 degrees. In the forceps it burns easily with a luminous sooty flame. It is partly soluble in alcohol, and ether. Its best solvent is turpentine.

Differences. It is readily distinguished from elaterite by not being elastic, for elaterite is an elastic variety of bitumen. It differs from wurtzilite in not possessing the black shiny or highly lustrous faces when broken.

Remarks. The asphalts vary widely in their composition. Some of them contain oils vaporizable at less than 100 degrees.

Some contain oils that volatilize at a temperature between 150 and 250 degrees. Some contain resins soluble in alcohol. Some carry solid asphalt like substances soluble in ether but not in alcohol. Some contain black or brownish black products not soluble in ether or alcohol. Some contain nitrogenous compounds. Kentucky is particularly favored in having an extensive deposit of rock asphalt well suited for the construction of permanent roads.

In the eastern field the asphalt lies in Carter County in the Chester sandstone. In the western field and more abundantly it occurs in Breckenridge, Edmonson, Grayson, Logan and Warren Counties. It is found in the Bee Spring sandstone of the Lower Conglomerate Coal Measures and in the Cypress sandstone.

THE OXYGENATED HYDROCARBONS

The oxygenated hydrocarbons occur as a constituent in the asphalts but it is not certain that any of them have been isolated and described. In general the mineralogist thinks of amber, a fossil resin, as the chief representative of this class, but many other more or less closely related substances belong here.

THE COALS

The coals are essentially compounds of carbon, hydrogen and oxygen. They are obviously derived from vegetable matter through the elimination of marsh gas, carbon dioxide and and water, together with several additional compounds, not necessarily the same in each case. The varieties of coal depend in part upon the amount of volatile constituents afforded upon destructive distillation, in part upon the nature of these compounds, and in part upon the structure, luster, hardness, and other physical properties.

The evidences that the various coals are of vegetable origin are as follows:

1—All stages of gradation from plants to anthracite coal.

2—Microscopic vegetable structure and composition.

3—Plants found changed to coal with bark, leaves, twigs, and leaf scars in perfect form.

4—From peat and sea weeds it has been artifically prepared in the chemical laboratory.

5—Timbers used as stulls and posts in the coal mines of England have become coverted into coal.

86—**Lignite.** Lignite is compacted and chemically altered vegetable matter retaining more or less of its original vegetable structure. It falls between peat upon one side and bituminous coal upon the other. Several different varieties exist which are based upon either composition or structure.

In color the lignites are brown or brownish black. Their streak approximates to the color of the coal tested. Their luster may be either pitchy or greasy. Their fracture is uneven. Their tenacity extremely brittle and their diaphaneity is opaque.

Pyrognostics. In the closed tube they yield water. In the forceps they burn with a luminous smoky flame. They afford a large amount of volatile matter and are non-coking.

Differences. Lignite is distinguished from other coals by its brown color, often closely resembling vegetable matter. It is richer in oxygen than the ordinary bituminous coal.

Remarks. Lignite occurs in Kentucky along the eastern margin of the Jackson Purchase in the Ripley sands and also within the Purchase in the La Grange sands of Eocene age. It is doubtful if it occurs in Kentucky as an economic mineral product.

87—**Cannel coal.** $\mathbf{C_{24}H_{26}O}$. The above formula is said to express the practical composition of cannel coal. It is a variety of bituminous coal. It differs from ordinary soft coal in texture and in composition as shown by the products of its distillation. It is the richest of all the coals in its volatile hydrocarbons. It graduates insensibly into an oil producing coaly shale, the compact varieties of which it closely resembles.

Its color is brown or brownish black. Its streak closely resembles the color of the coal tested but is paler and may be yellowish brown. It has little or no luster. Its hardness varies from 2 to 2.25 and its specific gravity from 1.15 to 1.35. Its fracture is conchoidal. Its tenacity brittle. Its diaphaneity opaque.

Pyrognostics. Cannel coal burns in a candle flame with a luminous sooty flame due to the large number of unsaturated carbon atoms. It is usually a coking coal. On distillation it yields from 40 to 66 per cent of volatile matter which consists in a large measure of fuel oils and lubricating oils.

Differences.

1—Cannel coal is more homogeneous in its intricate structure than the cubical coals.

2—There are no bright and dull lines as in peacock coal.

3—Like stratified rocks cannel coal sometimes shows perfect stratification as if deposited from aqueous suspension.

4—Cannel coal is the richest of all coals in its volatile hydrocarbons.

5—It is the richest of all coals in its illuminating power.

6—Cannel coal has more ash than other coals and passes directly into carbonaceous shales.

7—The fossils are aquatic animals, mollusks, crustaceans, amphibians and fishes.

8—Fern fronds are found fossilized in cannel coal.

Remarks. The sediments of carbonaceous sands in modern lagoons when dried closely resemble cannel coal. Cannel coal is the ideal fireplace fuel and the best American field for this fuel is Kentucky. Cannel coal occurs in the Eastern Coal Measures of Kentucky all of which are of Pennsylvanian age in Bell, Boyd, Breathitt, Carter, Clay, Crittenden, Elliott, Floyd, Greenup, Hancock, Harlan, Jackson, Johnson, Knott, Knox, Lawrence, Laurel, Leslie, Letcher, Morgan, Ohio, Owsley, Perry, Pike, Pulaski, Union, Whitley, Wolf Counties, and in the Western Coal Field in measures of the same age in Breckenridge County.

88—**Bituminous coal.** $\mathbf{C_{26}H_{20}O_2}$. The above formula practically represents the composition of several analyzed samples of bituminous coal. It often carries vegetable matter and retains much bitumen. Under the name of bituminous coal there occurs a large number of soft coals that differ widely in the products of their destructive distillation and therefore must differ widely in their composition.

The color of bituminous coal ranges from brownish black to black. Its streak is brown to black. Its luster is usually bright and pitchy. Its hardness varies from 1 to 2 and its specific gravity from 1.2 to 1.5. Its fracture is uneven. Its tenacity is intensely brittle. Its diaphaneity is opaque.

Pyrognostics. In the C. T. it yields water and volatile hydrocarbons. In the forceps it burns with a yellow smoky flame. On the charcoal it burns giving off oils or tar and leaving only a small amount of ash.

Differences. Bituminous coal is readily distinguished from anthracite by its extreme brittleness, by the absence of cubical fracture and by burning readily with a luminous sooty flame. It is distinguished from cannel coal by the absence of a conchoidal fracture. It is also darker in color.

Remarks. The coal fields of Kentucky comprise 15,130 square miles. Of this area 10,450 square miles are in the Eastern Coal Measures and 4,680 square miles are in the Western Coal Measures. All of these are of Pennsylvanian age. The Eastern Field comprises 37 counties and the Western Field 20 counties. With fuel coal present in Kentucky in 57 of the 120 counties of the State it forms one of the most important economic mineral products of this great Commonwealth. It is interesting to note that Kentucky stands fourth among the States in her output of bituminous coal. The volume in 1924 was 43,387,732 tons valued because of a depressed market at $88,745,968.00. In 1920 a little more than 38,000,000 tons was valued at about $159,000,000,00.

The End

THE ELKHORN COAL FIELD

BY

J. S. Hudnall

Assistant Geologist

One Map

THE ELKHORN COAL FIELD

By J. S. Hudnall
Assistant Geologist

The request for information on the Elkhorn Coal Field has been very urgent during the past decade. A general presentation of this important coal field has never been made in geological literature. The discussion herein presented is intended to outline the general extent of the field, its probable future extension and its relation to adjacent coal fields.

Definition and Areal Extent

The term "Elkhorn Coal Field" is herein defined as that portion of the Eastern Kentucky coal field within which the Elkhorn coal is mined. The Elkhorn coal is designated as the seam which is mined by the Consolidation Coal Company, at Jenkins, Ky. There is much confusion in regards to what coal is the true Elkhorn coal. The use of the names Upper and Lower Marrowbone as synonymous with Upper and Lower Elkhorn has added to the confusion. The Upper and Lower Marrowbone seams are not equal to the Upper and Lower Elkhorn, neither do they correlate with the true Elkhorn coal mined at Jenkins. The Upper Marrowbone correlates with the Van Lear, and the Lower Marrowbone is a correlative of the Pond Creek coal.

In the Elkhorn Coal Field there are three coals which lie very close together. In ascending order these are: the Wayland (No. 1), Van Lear (No. 2), and Elkhorn (No. 3). The interval from the Wayland to the Van Lear varies from two to sixty feet, usually being thirty feet. The interval from the Van Lear to the Elkhorn varies from thirty-five to seventy-five feet. This small interval between the coals has added much to the confusion of the identity of the Elkhorn coal. The Elkhorn coal in its type locality is a compound seam of two and sometimes three benches. The benches are separated by soft shale partings. The coal is best developed in its type locality at Jenkins, however, it is well developed and mined at Jenkins, Fleming, McRoberts, Weeksbury, head of Clear Creek, in Floyd County, and at Keyser, in Pike County. The Elkhorn Coal Field at the present time is limited to the area lying on the head of the North Fork of the Kentucky River above the mouth of Rockhouse Creek, in Letcher County; the headwaters of Right and Left Forks of Beaver Creek and the head of Big Mud Creek, in Floyd County, the drainage of Levisa Fork of Big Sandy River from Keyser up to a few miles above the forks in Pike County. This seam of coal will doubtless be mined over a much larger portion of Pike County than it now is. At the present time it can be identified and has a commercial thickness over most of the county. The Elkhorn coal is below drainage on Brushy Creek and the lower part of Johns Creek, in Pike County; the headwaters of Buffalo Creek, in Floyd County; the headwaters of the Kentucky River drainage, in Knott, Perry, Leslie, Harlan and Clay Counties.

Little is known relative to the thickness of the Elkhorn seam where it is below drainage, however it is reasonable to assume that it will be commercial in those areas adjacent to Pine Mountain.

CORRELATIONS OF THE ELKHORN COAL

The following correlations of the Elkhorn coal are made after four years of study of the stratigraphy of the coal measures in Eastern Kentucky, West Virginia, Virginia and Tennessee. The Elkhorn coal has been traced across Pike County and correlated with the Alma coal on the Tug Fork drainage in Kentucky and West Virginia. It is the No. 3 coal of Southern Floyd County. Across Pine Mountain it correlates with the Taggart coal of Harlan and Letcher Counties, Kentucky, and Lee, Wise and Dickenson Counties, of Virginia. In Knott, Whitley and Bell Counties it is tentatively correlated with the Jensen, Straight Creek, Pineville and Jellico coals, all of which are correlatives. It perhaps correlates with the C seam at Benham.

THE ANCIENT ELKHORN BASIN

From a study of the Elkhorn coal and its correlatives in West Virginia, Virginia and Tennessee the outline of the basin in which it was formed may be inferred. During the Pennsylvanian period at the time the Elkhorn coal was formed there was an elongate coastal plain or basin with a northeast and southwest axis extending from Jellico, Tennessee, through the Breaks of the Sandy into McDowell and Wyoming Counties, West Virginia. How far southwest of Jellico, Tennessee, and northeast of McDowell County, West Virginia, this basin extended is an open question. Probably it extended many miles to the southwest and northeast of the above points. The length of the basin was perhaps 150 to 200 miles and its width 75 to 100 miles. The center of this large coal-forming basin was perhaps in the vicinity of Jenkins, where the coal reaches its maximum thickness. Pine Mountain occupies a position near the center of the basin, hence it seems likely that a farther extension of this important coal field will be adjacent to Pine Mountain. This extension to the southwest in Letcher, Perry, Leslie and Harlan Counties will come with the development of shaft mining. The northern limit of this ancient coal basin is approximately along the line designated as ''the northern limit at which the Elkhorn coal may be identified'' on the sketch map accompanying this report.

The End

COAL LOSSES IN KENTUCKY

BY

F. E. Cash and C. A. Allen

In co-operation with the
Bureau of Mines of the
U. S. Department of the Interior

Illustrated with five coal mine map plates

LETTER OF TRANSMISSION

Dr. W. R. Jillson,
Director and State Geologist,
Kentucky Geological Survey,
Frankfort, Kentucky.

Dear Sir:

I have the pleasure in transmitting herewith for publication by the Kentucky Geological Survey, a report by F. E. Cash and the late C. A. Allen mining engineers of the Bureau of Mines, on the losses incurred in mining bituminous coal in the State of Kentucky.

This report presents the results of a survey conducted by the Bureau of Mines, Department of the Interior, in co-operation with the State Geological Survey, for the United States Coal Commission. This survey is part of the general inquiry made by the Federal Bureau of Mines into the losses that take place in the mining of bituminous coal in the eastern fields of the United States, those in the States of Alabama, Illinois, Indiana, Kentucky, Maryland, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia.

Very truly yours,

Washington, D. C.
March 3, 1925.

D. A. LYON,
Acting Director, Bureau of Mines,
Department of the Interior.

PREFACE

This bulletin embodies the results of a study of the losses that take place in the production of merchantable coal in the coal mining districts of Kentucky. The Bureau of Mines, Department of the Interior, and the Kentucky Geological Survey co-operated in this study, which was made for the U. S. Coal Commission. The coal-mine operators of the State cordially co-operated in supplying data requested, assisted in preparing records, maps, and estimates, and courteously facilitated the examination of mines and records.

The results obtained by this study are presented here in the belief that their presentation cannot but help the coal mining industry, because they call attention to the best practices and indicate some of the ways in which the amount of loss can be reduced without sacrifice of efficiency in operation.

W.R. Jillson

Frankfort, Ky.,
June 1, 1925.

Director and State Geologist,
Kentucky Geological Society.

COAL LOSSES IN KENTUCKY

By F. E. Cash and C. A. Allen

The eastern and western coal fields of Kentucky are entirely separate. The former accounts for about 70 per cent of the State's coal production, which ranges from 30 to 40 million tons per annum. The total in 1921 was 31,590,000 tons.

THE EASTERN FIELD

Districts—In order to study conditions in the best manner the eastern field should be divided into three districts—namely, Northeast, Hazard, and Harlan—which include all of the coal-producing counties in Eastern Kentucky.

Coal Beds Mined—There are eight beds being mined commercially. Details regarding them are given below:

BED	Output in 1921, Tons	Total loss, Per cent	Avoidable loss, Per cent
Harlan	6,000,000	31.0	15.0
Elkhorn	5,000,000	18.6	2.4
No. 6, or Hazard	3,000,000	31.0	6.0
No. 4, or Fire Clay	2,000,000	33.0	8.0
Miller Creek	2,000,000	25.0	1.0
Pond Creek			
Wallins Creek*	1,000,000	32.0	7.0
Wayland			

Mining Methods—The room-and-pillar system is in almost universal use. Variations in this system consist of differences in the width of rooms and the thickness of room pillars. In the majority of the mines, wide rooms are driven and thin pillars left. In a number of mines these pillars are left standing for a long time, a practice that increases the percentage of loss. Where the pillars are being taken on the advance, or even on the retreat with panels, the recovery is greater. The system of narrow rooms and thick pillars or blocks is giving the greatest recovery.

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*Correlates with the Fire Clay coal, or No. 4.

Losses—The following table gives the average percentage of loss, both total and avoidable, for all beds mined in Eastern Kentucky.

Average Coal Losses In Beds of Eastern Kentucky

REASON FOR LOSS	Percentage of marketable coal lost in area worked	
	Total loss. Per cent	Avoidable loss. Per cent
Coal left on roof and bottom..........	2.16	0.42
Coal lost in room, entry and panel pillars.	12.42	6.42
Coal lost in oil or gas-well pillars......	....	...
Coal lost under buildings, railroads and boundaries	0.30	...
Coal lost in handling and preparation, underground and surface	3.95	1.11
Coal lost due to rolls, thin or dirty areas, and surface streams (water crevices).	8.29	...
Total loss, per cent................	27.13	7.95

The losses are not due to one or two causes, but to most of them, and the variations are very irregular. The loss in pillars ranges from 3.5 to 16 per cent, and that due to rolls, thin and dirty areas, from 4.7 to 14 per cent. The loss in handling and preparation ranges from 3.5 to 4.8 per cent. The avoidable losses are also irregular. Pillar mining could be improved from 3 to 9 per cent, and handling and preparation from 0.7 to 1.6 per cent. As this field produces 19,000,000 tons of coal per annum and the average total loss is 27 per cent, the coal lost in 1921 amounted to 7,100,000 tons. The avoidable loss averages 8 per cent, therefore the coal that should be saved totals 2,100,000 tons. The remainder, 5,000,000 tons, constitutes the unavoidable loss. The average extraction of 73 per cent could be improved by about 8 per cent, making it 81 per cent.

THE WESTERN FIELD

In Western Kentucky there are 140 mines which produce a total of about 9,000,000 tons per annum (8,615,000 in 1921). Most of the coal comes from three beds, Nos. 9, 11 and 12, of which No. 9 is the lowest. The total losses in No. 9 bed and in No. 11 bed amount to 37 per cent in each, but the avoidable loss in No. 9 bed is 22 per cent, whereas in No. 11 the whole 37 per cent is unavoidable. The principal losses in No. 9 bed and No. 11 bed are in room pillars and entry pillars, few of which are recovered. Pillars could be extracted in No. 9 bed, if pillar drawing in No. 11 would affect the mining of No. 12 bed, which is seven to twelve feet above No. 11. Three per cent of the coal is lost in handling and preparation, practically the same proportion as in the Eastern Kentucky fields. The total loss of coal in the Western District in 1921 was 5,000,000 tons. The extraction was 63 per cent, but as 22 per cent of the total loss that is avoidable is in the bed that produces 78 per cent of the coal, 80 per cent of the total coal should be recovered.

COAL LOSSES IN THE HAZARD DISTRICT, KENTUCKY

By F. E. Cash

INTRODUCTION

The district covered by this report includes the counties of Perry, Breathitt, Knott and Letcher, and covers about 300 square miles. It is bounded on the north by Lost and Troublesome Creeks, east by Sandlick Creek, and on the south and west by the North Fork of the Kentucky River. The surface is mountainous, with narrow valleys and numerous streams. Long railroad spurs extending up the principal streams serve this field. The branch up Sandlick also handles some of the Elkhorn coal discussed in the report on the Northeast District. In the Hazard field are about eighty operations which produce a total of 6,000,000 tons annually. The first coal was shipped from No. 4 bed in 1912.

Two trips were made underground in No. 6 (Hazard) and one in No. 4 (Fire Clay) bed; while general data were obtained on twenty-one mines working No. 6, on twelve mines working No. 4, and on one working No. 7 (Flag) bed.

CHARACTERISTICS OF PRINCIPAL BEDS

The principal beds mined are the Fire Clay or No. 4, which is the lowest, and the Hazard or No. 6. The Flag or No. 7 is mined in a few places.

The Elkhorn bed in this district is mined by two large companies, whose methods and recovery are similar.

The Fire Clay, or No. 4 bed, invariably carries a 3 to 6-inch flint-clay parting. This bed is 30 to 72 inches thick, averaging for the district 42 inches of coal. Where the bed thins down to 36 inches or less the flint clay forms the bottom, and where it thickens, about 42 inches of coal lies above the parting and the remainder below. A representative analysis, supplied by W. N. Cole, of Hazard, Kentucky, is as follows:

Constituent	*Per Cent.*
Fixed carbon	58.37
Volatile matter	36.97
Moisture	1.42
Ash	3.24
Sulphur	0.61
B. t. u.	14,482

Several seams lie between the No. 4 and No. 6 beds; 235 feet above the No. 4 is the No. 5 or Haddix, and 80 feet above the No. 5 is the No. 6 or Hazard. The intervening strata are sandstone, shale, and thin limestones. At present the No. 6 is the most productive bed in the district. Its thickness ranges from 48 to 84 inches, with an average of 60 inches. The character of the bed differs in different places. A bone parting one to three inches thick lies near the bottom of the bed, and is thickest where the coal is thick. Other bone partings are found in certain localities but are by no means general. An average analysis, supplied by W N. Cole, is given herewith:

Constituent	*Per Cent.*
Fixed carbon	56.32
Volatile matter	37.16
Moisture	1.92
Ash	4.60
Sulphur	0.56
B. t. u.	13,823

Sixty feet above the No. 6 with shale and sandstone between, comes the Flag or No. 7 bed. This averages 52 inches in thickness, has a 1-inch bone parting 12 inches from the bottom, and closely resembles the No. 6 bed. In very few places are both the beds workable, and where they are being mined the No. 7 is being exhausted before pillars are drawn in the No. 6.

All three beds are in places overlaid with two to ten inches of draw-slate which is left up in the rooms. Above this is heavy sandstone. Generally speaking, the roof is good. The bottom is slate, which generally is hard.

Props are set three to six feet apart in rooms, and rarely are there any cross-bars in entries. No heaving of the bottom is experienced except occasionally where, in No. 4 bed, some coal is left under the flint-clay parting.

The average cover of No. 7 bed where worked is 200 feet; of No. 6, 250 feet; and of No. 4, 300 to 400 feet. The surface is practically of no value except for the mine timber on it.

The fracture lines are good, and mining is carried on so as not to hinder working the bed above where it is of workable thickness.

MINING METHODS

All mines are opened by drifts, and are worked by the double-entry room-and-pillar system. Narrow rooms and thick pillars are being used where they were not originally employed in the more recent developments. Practically the same methods are being used in all of the beds.

As is shown in Figure 1, the rooms are driven in pairs, 18 feet wide, with an 18-foot pillar between; a 65-foot block is left between this and the next pair of rooms. This plan is replacing 36-foot rooms on 65-foot centers. Main entries are generally 12 feet wide, though a few are 16 feet. Cross entries are 12 to 14 feet wide, and pillars between main and cross entries 50 to 60 feet. Break-throughs are on 60 to 80-foot centers and are 12 feet wide. Barrier pillars are 100 feet wide. The coal is undercut by shortwall machines, with six to seven-foot cutter-bars.

The theoretical recovery is 23 to 32 per cent by first mining, and 68 to 77 per cent by second mining.

LOSSES IN MINING

Planimeter calculations are of no value in calculating losses in mining, because when an area is exhausted, engineers show it as all taken. However, close figures were obtained from the engineering department of one large operator as follows, for No. 4 (Fire Clay) bed:

REASON FOR LOSS	Percentage of marketable coal lost in area worked Total loss	 Avoidable loss
Roof coal left	..	..
Bottom coal left	2	2
Boundaries	2	1
Handling	4	1
All pillars	15	5
Thin and dirty areas	10	..
Total loss, per cent	33	9

The No. 6 (Hazard) and No. 7 (Flag) beds are not developed enough to make figures available, but as they lie above the No. 4 (Fire Clay), the following estimates will be conservative for both of them:

REASON FOR LOSS	Percentage of marketable coal lost in area worked Total loss	 Avoidable loss
Roof and bottom	..	..
Room, entry and panel pillars	15	5
Boundaries	2	1
Handling	4	1
Thin and dirty areas	10	..
Total loss, per cent	31	7

AVOIDABLE LOSSES

As the old method of room-and-pillar mining, wide rooms and thin pillars, is replaced by narrow rooms and thick pillars, the loss will decrease. In the future it will be possible to make the recovery 83 per cent for the district, which will bring the recovery of the original coal from the past and present figures of 67 to 73 per cent up to 80 per cent.

ACTUAL FIGURES ON RECOVERY

The engineer and superintendent of one corporation (No. 1) mining Nos. 4, 6 and 7 beds, gave the figures below which do not include bottom coal left or coal in thin and dirty areas. Another corporation (No. 2) gave figures for Nos. 4 and 6 beds.

BED NO.	Loss, per cent No. 1	No. 2
4 (Fire Clay)	10-15	27
6 (Hazard)	15	20
7 (Flag)	5-10	..

A study of a number of mine plans reveals the following conditions:

1-a. Working the Hazard or No. 6 bed shows coal left and probably lost on account of crop conditions. The hills are very steep and cannot be stripped, and will not warrant new openings to recover it. A few small stumps or pillars have been lost in taking the pillars or blocks. The method of working narrow rooms and big pillars or blocks increases recovery.

1-b. An area has been left around the outcrop. Extensive advance or development work has been done, and all pillars have been left in. This will increase the cost of recovery and increase the probability of losing more pillar coal.

2. Two mines working the Fire Clay or No. 4 bed show good entry development, but lack of system in room work. The development in No. 2 mine will permit higher recovery than that in No. 1 because larger pillars have been left.

3. This mine is working Nos. 4 and 6 beds, and shows the first methods of mining in this field. Apparently the first operators planned to get all the coal possible on the first mining, and gave no thought to pillar work. New development, however, is all on centers with the purpose of taking the pillars on the advance or retreat.

Engineering and mining methods are rapidly being improved. Recovery is being closely studied by the holding companies. Experienced inspectors make regular inspections of all places in the mines. Therefore the percentage of loss should diminish as developments and improvement in methods continue.

Summary of Coal Losses in Hazard District

REASON FOR LOSS	Percentage of marketable coal lost in area worked	
	Total loss	Avoidable loss
Coal left on roof and bottom	1	1
Coal lost in room, entry and panel pillars	12	3
Coal lost in gas-well pillars	..	..
Coal lost under buildings, railroads and boundaries	2	1
Coal lost in handling and preparation, underground and surface	4	1
Coal lost due to rolls, thin and dirty areas and surface streams (water courses)	11	..
Total loss, per cent	30	6

COAL LOSSES IN THE NORTHEAST DISTRICT, KENTUCKY

By F. E. Cash

Introduction

The Northeast District, as treated in this report, is divided on a production basis into two parts: a major and a minor field. The latter or minor field consists of two small areas—one in the western part of Boyd County and one in the southern part of Carter County. The major field, which produces most of the coal, includes the southeastern corner of Lawrence, the eastern half of Johnson, all of Floyd, the western half of Pike, a small area in the northeast section of Knott, and the extreme western corner of Letcher County. Production in 1921 was as follows:

County*	Shipping mines	Tons
Boyd	8	128,268
Carter	11	116,585 (in 1922)
Floyd	78	2,528,006
Johnson	14	589,537
Knott	3	64,328
Lawrence	5	104,370 (in 1922)
Pike	44	438,310
Total	163	3,969,404

The total production from this field was 5,684,935 tons in 1920; 3,997,104 tons in 1921; and 6,133,077 tons in 1922. The annual production chart compiled by the Northeast Kentucky Coal Operators' Association shows that the growth in production from 1906 to 1922, inclusive, was as follows:

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*With the exception of Floyd County these are all fractional County production figures as indicated above.

Capacity and cause of reduction thereof	Tons	Per cent
Potential full-time capacity	15,507,148	100.00
Production	6,133,077	39.55
Production lost through all causes......	9,374,071	60.45
Production lost through car shortage....	5,987,310	38.61
Production lost through labor shortage..	519,489	3.35
Production lost through strike........	646,647	4.17
Production lost through mine disability	1,855,669	1.40
Production lost through other causes..	117,856	0.76

The following beds are named in the order of their importance: (1) Elkhorn or; (2) Millers Creek and, (3) Wayland, Freeburn and Amburgy; but only the first two are considered here. The product is a high-grade bituminous coal and is used for raising steam, for household purposes and for making coke.

Three trips were made underground in this field seeing sections of seven mines; three other operators were interviewed, and data were secured from four others.

Characteristics of Coal Beds

Millers Creek or Van Lear. This bed is extensively mined on the Levisa Fork of the Big Sandy River in Floyd and Johnson Counties. The best development as to thickness and workable area is on Millers Creek and at the mouth of Johns Creek, both of which are tributaries of the Levisa Fork. This bed has been termed Elkhorn No. 2. The thickness ranges from 18 to 60 inches, and averages 40 inches. Generally speaking, the bed carries no partings. In small local areas there is a ''jack rock'' parting, 3 to 18 inches thick, and in other places there is a slate parting two to three inches thick.

When either of these partings occur, it is near the bottom, on top of 18 inches of coal. In places this coal is left.

The following sections, furnished by an operator at Prestonsburg, Kentucky, are representative of the bed:

County	Place	Section of Bed
Floyd	½ mile west of Prestonsburg. . . .	Roof, slate. Coal, 48 inches. Bottom, slate.
Floyd	1½ miles west of Prestonsburg. .	Roof, slate. Coal, 30 inches. Rock, 18 inches. Coal, 20 inches. Bottom, slate.
Floyd	2 miles northwest of Prestonsburg	Roof, slate. Coal, 36 to 50 inches. Parting, slate, 2 inches thick, 18 inches from bottom. Bottom, slate.
Johnson	1 mile southeast of Auxier	Roof, slate. Coal, 48 to 60 inches. Bottom, slate.
Johnson	North of Paintsville	Roof, slate. Coal, 48 inches. Bottom, slate.

The roof of the Millers Creek bed is generally of slate, which varies widely in thickness, from a knife-edge to 40 feet; occasionally the sandstone comes down to the coal. In a few places one to five inches of draw-slate lie over the coal, and is taken down or comes down. No roof coal is left in this bed. The roof, which is shale or, in places, sandstone, is excellent. The floor is fireclay of medium hardness.

Data on this bed were obtained from fifteen openings. Mining was first begun in 1905, and so far has been continuous. The probable future life is about seventy years.

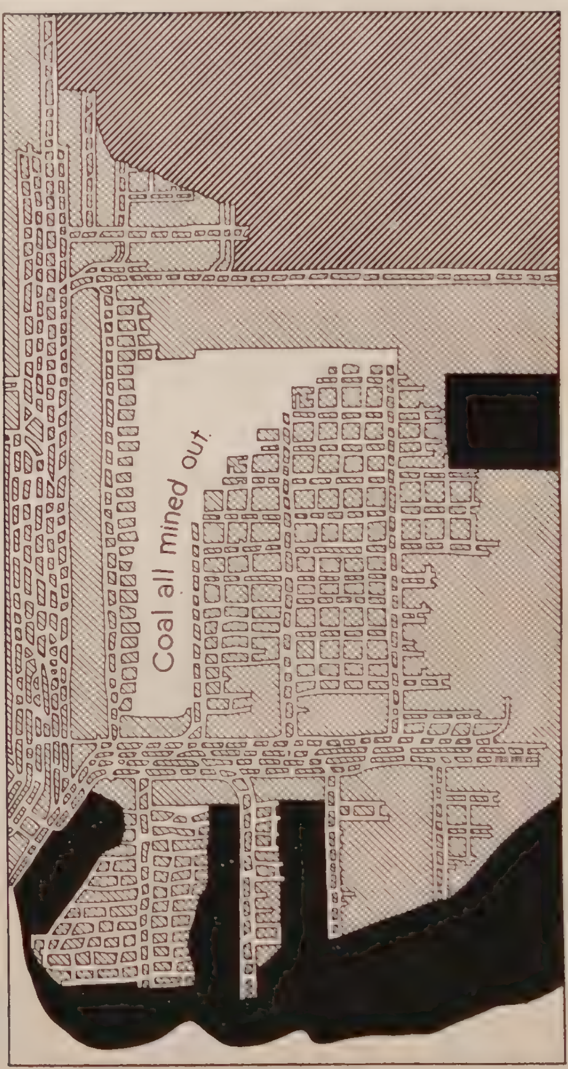
In this district the surface is very rough and mountainous and is of very little value except for the mine timber growing on it. The present workable coal outcrops at many points above the railroad. The cover varies from 40 to 800 feet. The next workable bed is 175 feet above, with slate and sandstone intervening. In the opinion of the operators, as well as the investigator, this bed is not interfered with by mining the one below, although the bed above has not been developed over the Millers Creek bed.

Elkhorn and Van Lear. The Van Lear or Millers Creek coal, and the Jenkins or true Elkhorn seam are two distinct coal beds. The Van Lear coal is extensively mined on the Big Sandy, and the Right and Left Forks of Beaver Creek, in Floyd County. The Elkhorn bed, mined at Jenkins, McRoberts, Fleming, Seco and elsewhere in this vicinity, is generally divided into the upper and a lower, by a clay parting that ranges from a streak to six feet in thickness. The probable average thickness of this parting for the entire bed is 10 inches. However, in certain localities, these two benches of the Elkhorn bed are separated by 20 or 30 feet of intervening strata.

The roof of the Elkhorn bed is shale and sandstone and, generally speaking, is good. In a few localities there is draw-slate, ranging in thickness from 1 to 30 inches, which comes down or has to be held up, and occasionally the shale over this draw-slate is not very strong. The floor of the Elkhorn bed is hard shale, and little trouble is encountered except when the upper bench is being worked and the lower one is left under the parting. Frequently 18 inches of roof coal is left in the Elkhorn bed.

Mining Methods

Practically all the mines are opened by drifts, and the room-and-pillar method of mining is generally employed, although this is being rapidly modified by a panel system with narrow rooms and thick pillars or blocks. Where the room-and-pillar methods are employed without modification, the main entries are driven 12 to 20 feet wide, across entries 18 to 20 feet, and butts 18 to 20 feet, with 18 to 20-foot chain pillars. The barrier-pillars vary from 50 to 110 feet, and rooms are driven on 35 to 60-foot centers, with 20 to 30-foot pillars. Break-throughs are 60 to 100 feet apart, and 12 to 18 feet wide.



SECTION OF MINE MAP
Northeast District, Kentucky

▨ Virgin Coal
▧ Coal that will be extracted in part or in whole
■ Coal Lost

Fig. 2.

The operations producing the bulk of the tonnage are using a modified room-and-pillar method. Figure 2 shows this method admirably well. All entries are 12 feet wide. The rooms are driven 12 feet wide on 90 and 100-foot centers, and the cut-throughs leave 80 to 90-foot blocks. These blocks or pillars are taken either on the advance or retreat, or both ways in the same mine. The recovery by this system is greater than by the modern room-and-pillar method, and far in advance of some of the old room-and-pillar development.

There are only a few places where entries are driven wide and the additional width used for piling rock or gobbing.

Seventy-five per cent of the coal is mined by machines.

The account that follows is taken from information given by the chief engineer for a company mining the Elkhorn No. 3 at Weeksbury, Kentucky.

Following is a brief description of the difficulties which must be overcome and a description of our plan as we found necessary to apply for economic mining practices:

Condition: Narrow room centers, as applied to bituminous mines in low seams, 30 to 48 inches, and grades permitting development without severe handicap to haulage and drainage.

Difficulty: Room-and-pillar method of mining in seams of 36 to 48 inches always presented the question of minimum heading development on account of the yardage involved. This leads to a tendency to lengthen rooms and pillars to distances found impracticable. Long rooms in low seams invariably result in dissatisfied labor or additional compensation for miners to drive rooms to limit and retreat with pillar.

Rooms and pillars in low seams on wide centers always involve additional expense and trouble to driving crosscuts or cut-throughs for ventilation purposes. Consequently, where advance of rooms and retreat of pillars cannot be carried on systematically, the delayed development necessitates additional mine equipment and heading development in order to obtain the tonnage demanded.

Plan Desired: Therefore, under and where these conditions exist, the short room and narrow room-and-pillar centers offered rapid development, on account of rooms being worked from both heading and air course. The maximum number of rooms and pillars can be worked advancing, giving the greatest tonnage possible. Concentration of working places means minimum day labor. Driving short rooms on narrow centers permits removal of pillars before room conditions become badly affected. Pillaring on the advance not only permits concentration of working places but also the advantage of relieving material for re-use. Advance pillaring, unless roof conditions are extremely bad, permits sectional slabbing of pillars which is preferable to removing on end and is less expensive.

Results of Plans: Rooms of medium short length driven on narrow centers, and removal of pillars advancing on a practical system, should and do offer the following advantages: Maximum tonnage from given area; concentration of working places, permitting a smaller working force inside, including haulage; minimum amount of material, such as ties, rails, etc., and the possible re-using of same, and the maximum recovery of seam

Some companies purchase and some generate their power. Where power is generated locally, about 1 per cent of the coal mined is used for it; but where possible, power is purchased because purchase is more economical.

CALCULATION OF LOSSES

Where the recovery figures are accurately kept they afford the best gauge to sustained losses. Some of the companies have these figures calculated for each month, and the tonnage from the exhausted and abandoned ground must check with the developed area. Where these figures are not kept and all of the abandoned area is shown on the maps as recovered it is necessary to estimate from what can be seen and from what information can be obtained.

In view of the fact that when development first began in this field the room-and-pillar method was employed and worked in a crude way, the final recovery is good and will improve. For the Millers Creek bed the losses in roof and bottom will be 1 per cent. This is due to the rock parting that lies near the bottom in places, and cannot be removed economically, it is thought, to get the three to six inches of coal below. The loss in all pillars will not exceed 5 per cent; the loss in handling and preparation underground and surface 3 per cent; and the loss due to rolls, thin or dirty areas and surface streams, 16 per cent. The total loss is therefore 25 per cent. Around Paintsville and to the west this bed thins in places, and when it gets as thin as 30 inches it is not developed, but it can be mined when its mining becomes profitable.

In the Elkhorn bed the losses in roof and bottom amount to 3 per cent; in room, entry and panel pillars, 2 per cent; in handling and preparation underground and surface, 4 per cent, and loss due to rolls, thin or dirty areas and surface streams, 12 per cent. The total loss is thus 21 per cent.

ACTUAL EXTRACTION

The following figures were supplied by engineers and managers of producing mines:

1. Prestonsburg—Loss in pillars, 10 per cent; loss through rolls, thin and dirty areas, 25 per cent, making a total of 35 per cent.

2. Prestonsburg—Loss in pillars, 10 per cent.

3. Paintsville—Losses in pillars and preparation, 8 per cent; losses in rolls and thin areas, 25 per cent, making a total of 33 per cent.

4. Weeksbury—Loss in pillars, 10 per cent.

5. Van Lear—During the year 1920 the acreage exhausted was 56.189, and acreage abandoned and lost, 6.653; in 1921 the acreage exhausted amounted to 61.553, and acreage abandoned and lost, 4.096; in 1922 the acreage exhausted amounted to 21.695, and acreage abandoned and lost, 4.714. For the three years the acreage exhausted amounted to 139.437, and acreage abandoned and lost amounted to 15.463.

The acreage abandoned and lost includes the acreage abandoned because the coal is not of workable height, the acreage abandoned because of faults, the acreage abandoned on account of reservations, and the acreage lost in actual mining. The 15.463 acres were divided as follows: Actual loss in mining, 7.647; reservations, 2.469; unworkable coal because of faults and insufficient height, 5.320. The actual loss in mining is, therefore, 7.647. Subtract this from 15.463 acres, leaves 7.816 unavoidable loss. Adding 139.437, the exhausted area, to 15.463, gives 154.900, the total acreage. Subtracting from this total acreage the unavoidable loss, 7.816, gives 147.084 acres that could be worked. Dividing this into 139.437, the exhausted acreage, gives an average recovery of 94.8 per cent.

1920	334,403 tons
1921	395,761 tons
1922	136,676 tons
Total	866,840 tons

But the actual tonnage for the exhausted area for this period amounted to

1920	344,439 tons
1921	373,181 tons
1922	137,769 tons
Total	855,389 tons

Actual tonnage, therefore, is 98.67 per cent of calculated exhausted tonnage, and 94.8 per cent x 98.67 per cent total recovery, gives a recovery of 93.53 per cent.

With respect to coal reserves, this field is young. Although some of the earliest companies did not employ the best mining methods for obtaining a high recovery, those methods are being improved. The newer operations are employing better methods, the best engineering forces possible, handling and preparing coal in the most modern way and, as a rule purchasing the power they require. The recovery of the coal down to a minimum thickness of 30 inches is good; the working of thinner coal is being considered economical.

Summary of Coal Losses in Northeast Kentucky

REASON FOR LOSS	Percentage of marketable coal lost in area worked	
	Total loss	Avoidable loss
Coal left on roof and bottom	2	2
Coal lost in room, entry and panel pillars	3.5	..
Coal lost in oil or gas-well pillars	None	..
Coal lost under buildings, railroads and boundaries	None	..
Coal lost in handling and preparation, underground and surface	3.5	0.7
Coal lost due to rolls, thin or dirty areas and surface streams	14.0	..
Total loss, per cent	23.0	2.7

The coal lost in this district during 1921 amounted to 1,330,000 tons.

COAL LOSSES IN THE HARLAN DISTRICT, KENTUCKY

By F. E. Cash

INTRODUCTION

The following counties comprise the Harlan district: Bell, Harlan, Knox and Whitley. The region is drained by the Poor Fork, Clover Fork, Wallins Creek, Catrons Creek and Clear Creek, all tributaries of the Cumberland River. The Poor and Clover Fork and Catrons Creek unite just east of Harlan, in Harlan County, and form the Cumberland River, into which Wallins and Clear Creeks flow between Harlan and Pineville. Pine Mountain bounds this district on the north, and the Virginia-Kentucky and Tennessee-Kentucky State lines on the south.

The Harlan district produced approximately 9,000,000 tons in 1921. Whitley County, with 15 operations, produced 413,566 tons; Knox County, with 13 operations, 426,480 tons; Bell County, with 53 operations, 1,366,613 tons, and Harlan County, with 58 operations, 6,796,481 tons.

The three principal beds mined, in order of importance, are the Harlan, Wallins Creek and Elkhorn.

In the study of this district, three trips were made underground, one in each bed. Information was obtained regarding 11 operations and maps of them were studied.

A good grade of bituminous coal is produced. The Elkhorn is an especially good coking coal; both the Harlan and Wallins Creek are good domestic and steam coals.

CHARACTERISTICS OF BEDS BEING WORKED

Elkhorn Coal. The Elkhorn coal is being mined on the headwaters of Poor Fork of the Cumberland River. The thickness ranges from 48 to 72 inches, with an average for this field of 63 inches of marketable coal. There is a 3-inch slate parting in a portion of one mine working this bed, but so far as could be ascertained, the coal is free from partings elsewhere in this area. A little over 2,000,000 tons were extracted from this bed in 1921.

Wallins Creek Coal. The Wallins Creek coal has not been under development as long as either of the other beds, but production from it is growing rapidly. The average thickness of the bed in this district is 66 inches. The maximum thickness is in the Wallins Creek section of Harlan County, where the bed shows 82 inches of coal, a 6 to 12-inch parting, and 18 inches of coal below the parting. The coal under the parting is rarely mined. About 1,000,000 tons were mined from the Wallins Creek bed in 1921.

Harlan Coal. The Harlan is the main producing bed in the field at present, approximately 6,000,000 tons being mined from it in 1921. The thickness ranges from 40 to 52 inches, with an average for the district of 44 inches. North of a line from the mouth of Turtles Creek on Martins Fork, in Harlan County, to the mouth of Blacksnake Branch on Brown's Creek, in Bell County, the bed shows 48 inches of clean coal. South of this line there is a three-inch slate parting, 18 inches from the bottom, over one-eighth of the area underlaid by the bed.

NATURE OF COVER, ROOF AND FLOOR

The surface is of practically no value except for the mine timber growing thereon. The hills are very steep, and the coal lies above drainage.

The Elkhorn has a cover ranging from 50 to 2,700 feet, with an average of 1,000 feet for the area worked; the Wallins Creek has 50 to 800 feet, with an average of 600 feet; and the Harlan has 50 to 1,500 feet, with an average thickness of 600 feet for the present developed area.

The three beds mined have undulating floors. For the Harlan the floor is fireclay over sandstone, and for the Wallins Creek and Elkhorn it is shale of medium hardness. In one mine inspected, working the Harlan bed, the coal had been left under the parting, the cover was about 1,500 feet thick, and the immediate roof was sandstone. Although the maps examined did not show any lost pillars, it is probable that a fairly large area of pillars had been left and lost at some time in the past, because a squeeze on a considerable area of the mine was causing the bottom to heave, and the top gave so much so that the bottom and top were together in a number of places without any sign of a break, fall, or fracture line. The top generally is good over all three beds, and when it is properly handled, the proper falls are easy to get.

Mining Methods

A representative mine working the Wallins bed employs the room-and-pillar method developed as follows: All headings are driven 12 to 15 feet wide, with 30 to 35-foot pillars between heading and air course. Left and right headings are driven off main or face headings on 340-foot centers; and off of these headings the rooms are driven to the right or left, depending upon the dip. The rooms are necked 12 to 16 feet wide for a distance of 40 feet, then widened to 45 feet for 220 feet, or to within 10 or 20 feet of the next entry. The break-throughs between headings are on about 75-foot centers, and are 12 to 15 feet wide. The break-throughs in rooms are farther apart, and as a rule there is only one in a room. The theoretical recovery is 60 per cent on first and 40 per cent on second mining.

Figure 1 shows the coal left, which probably will be lost because the hills are too steep for stripping, and the coal will hardly warrant additional or new openings later. It also shows room pillars which will probably be lost on account of being left a long time, rooms being allowed to cave or fall; also because the pillars are small and cleaning up rooms to get the pillars will not be considered economical. It is probable that a number of pillars not outlined will not be recovered.

The method used in the Harlan bed is, generally speaking, almost similar to that used in the Wallins Creek, although the layouts have not been followed as closely as in the latter bed. When the Harlan bed was first mined, some of the mines were developed apparently to recover all coal on the first mining, as the rooms were driven wide, not on centers, and with a very thin pillar. Maps showing the coal actually left underground and with the fall lines marked were not often available. Considerable coal has been lost in this bed through creeping, squeezing and heaving. This loss has been caused primarily by bottom coal left under a parting, and secondarily by the creeps, squeezes and heaves interfering with recovery of pillar coal.

The Elkhorn bed is being mined on a modified room-and-pillar system, carrying with it panels with narrow rooms and thick pillars. The pillars are systematically recovered by a half-advancing and half-retreating method.

All entries are 12 feet wide and the cross entries are 400 and 600 feet apart. The entry and room break-throughs are on 80-foot centers and are 12 feet wide. The rooms are driven 14 feet wide, and 28 feet of coal out of each 100 feet is taken on the advance. At present one large operating company is leaving 1,000-foot boundary pillars developed for recovery later. The recovery in this bed is going to be good, principally because of the engineering and mining methods.

Calculation of Losses

Some bottom coal is left in all three of the beds, and the amount of total marketable coal was calculated by ascertaining the area carrying the parting under which the bottom coal is being left and figuring it against the total coal areas. The coal lost in all pillars is more or less of an estimate; only a few companies at present are drawing pillars, but state that they expect to do so. The figures for the rolls, and thin or dirty areas were obtained from the engineer for a company at Harlan. The bottom and top coal being left in the district in the three beds amounts to 2.3 per cent, in all pillars 16 per cent, in handling and preparation 4.8 per cent; rolls, thin and dirty areas, 4.7 per cent. The total loss of the three beds, figured against the production, will average 27.8 per cent for the district, and the coal lost in 1921 amounted to 2,480,000 tons.

Avoidable Losses

There are practically no buildings or railroads above either of these beds, consequently no reservations are necessary. Two per cent of the loss in handling underground could be avoided if the coal were properly separated from the partings and less of it left in exhausted areas. This applies to the Harlan and Wallins Creek beds.

In the Harlan, 13 per cent, and in the Wallins Creek, 5 per cent more coal could be recovered from pillars had the rooms been driven narrower, and had a systematic procedure in pillar drawing been followed at the beginning. Losses in these two beds are, however, being minimized as quickly as possible, and the new development will show an increased recovery of pillar coal.

ACTUAL EXTRACTION

Officials of three companies gave the following figures of actual extraction of coal:

1. Harlan bed, 80 per cent; Wallins Creek bed, 85 per cent.
2. Elkhorn bed, 93 to 97 per cent.
3. Elkhorn bed, 95 per cent.

The better recovery in the Elkhorn bed 93-97 per cent, as compared with 80 per cent in the Harlan and 85 per cent in the Wallins Creek, is due largely to improved engineering and mining methods. But methods in the Harlan and Wallins Creek are being improved, and the recovery from these beds will gradually increase.

SUMMARY OF COAL LOSSES IN HARLAN DISTRICT

REASON FOR LOSS	Percentage of marketable coal lost in area worked	
	Total loss	Avoidable loss
Coal left on roof and bottom	2.3	..
Coal lost in room, entry and panel pillars	16	9.2
Coal lost in oil or gas-well pillars	None	...
Coal lost under buildings, railroads and boundaries	None	...
Coal lost in handling and preparation, underground and surface	4.8	1.6
Coal lost due to rolls, thin or dirty areas and surface streams	4.7	..
Total loss, per cent	27.8	10.8

COAL LOSSES IN WESTERN KENTUCKY

By C. A. Allen

INTRODUCTION

The Western Kentucky field includes the counties of Henderson, Union, Webster, Hopkins, Daviess, Ohio, McLean, Muhlenberg, Christian, Crittenden, Butler and Hancock. According to the Kentucky Geological Survey, in 1920 there were in this field 97 mines working the No. 9 bed, 27 mines the No. 11 bed, 7 mines the No. 12 bed, 2 the Mannington bed, and 10 working unclassified beds. According to the survey the production in 1921 was as follows:

County	*Tons*
Crittenden	1,644
Christian	123,702
Daviess	93,021
Hancock	4,696
Henderson	340,720
Hopkins	1,997,609
McLean	91,306
Muhlenberg	3,223,952
Ohio	863,185
Union	821,300
Webster	1,054,721
Total	8,615,856

Of this tonnage, 6,708,971 tons came from No. 9 bed; 1,136,850 tons from No. 11 bed, and 265,822 tons from No. 12 bed; the remainder came from mines on miscellaneous or unclassified beds. The figures indicate a large number of mines with small outputs. In studying this field the writer made two trips underground to examine No. 9 bed and one trip in each of Nos. 11 and 12 beds. Data were obtained on 23 mines with a total production of about 5,000,000 tons.

GEOLOGICAL CONDITIONS

The outcrop of the coal beds being worked in this field extends along an irregular east-west line passing through Wheatcroft, Earlington and Greenville. The dip ranges from one to two degrees to more than ten degrees in places to the north; consequently the coal to the north soon gets under fairly deep cover, while to the south it appears only in the tops of the hills. The lower beds, of course, outcrop farther south than the upper beds. As a result some of the work in the lower beds is being carried on south of the crop of the upper beds, and some of it, where the workings have reached greater depth, is under the upper beds, as is shown by Figure 3. For the purposes of this investigation No. 9 can be considered the lowest bed being worked, although a very small tonnage was coming from still lower beds. No. 11 bed lies 70 to 100 feet above No. 9, averaging about 80 feet. The intervening strata are said to consist of shale in the lower part and sandstone or sandy shale in the upper part. The interval between No. 11 and No. 12 beds varies; in places the beds come together, but usually they are 7 to 12 feet apart. There is nearly always, but not always, about four feet of strong limestone between the two beds when they are any distance apart. In other words, although No. 11 and No. 12 both underlie a large part of the area, the interval between them and the character of the intervening rock frequently vary in places. No. 12 is absent and in places No. 11 is too thin to be of commercial importance.

Figure 3 shows the stratigraphic relations of the beds and the proportion of the total output the beds produce.

Characteristics of No. 9 Bed

No. 9 bed is 4 feet 7 inches to 6 feet thick, averaging about 4 feet 10 inches. It has no regular impurities, but carries occasional lenses of sulphur. The roof is a hard shale, which in the western part of the field contains numerous large boulders such as are typical of the roof of No. 5 coal in Indiana. The floor is of clay, but usually is very firm. Altogether the conditions for mining are nearly ideal

CHARACTERISTICS OF NO. 11 BED

No. 11 bed is six to seven feet thick at Earlington and five to five and one-half feet thick where it is being worked farther west, but in some places in the western area it is said not to be found at all. It has two very characteristic dirt bands. One called the blue band, corresponding to the blue band in the No. 6 bed of Illinois, is 18 inches above the floor and is about two inches thick. The second regular impurity is a very thin band 14 to 16 inches from the roof. Above this upper band the coal is said to be of superior quality. The immediate roof over No. 11 is usually shale, which in most places is very thin; immediately above it is the limestone which makes a remarkably good roof. At those places where the shale thickens it causes considerable difficulty in disposing of it, but this is rarely the case. The floor is clay, which softens badly when wet.

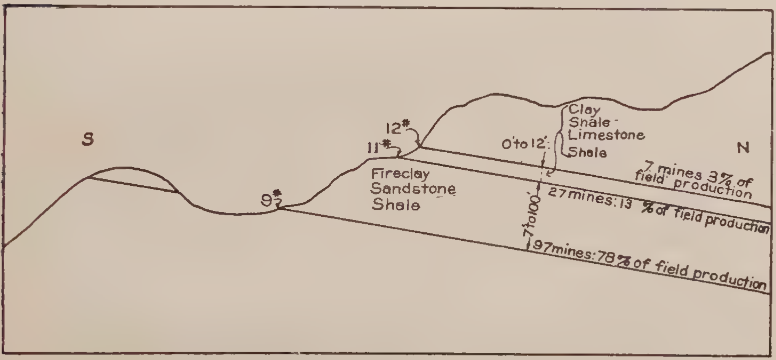

S
12#
11#
9#
Fireclay
Sandstone
Shale
0'to 12'
Clay
Shale
Limestone
Shale
N
7 mines 3% of field production
27mines: 13 % of field production
7'to 100'
97mines: 78% of field production

Fig. 3.—Cross Section Beds in Western Kentucky

CHARACTERISTICS OF NO. 12 BED

From the information that could be gathered, No. 12 bed seems to be irregular both as to thickness and quality of the coal. At Earlington it is said to be three to four feet thick and of questionable quality. A stripping operation in this vicinity has been mining both Nos. 11 and 12, and it is said that they have had to mix the coal from the two beds in order to get No. 12

on the market, as the latter could not be sold alone. At Greenville, where No. 12 is about five feet thick, it carries about 15 per cent of ash, but otherwise it seems to be a good coal. At Central City, No. 12 is said to be three feet thick, and is not considered workable. Near Clay, in the western end of the field, No. 12 is being worked, and is six to eleven feet thick, with a number of thin clay partings, about four inches of bony coal forming the top of the bed. The coal is said to be lower in sulphur than that from Nos. 9 or 11, and for that reason is in demand as a gas coal. The roof consists of three to four feet of clay which caves very readily, and for that reason about 15 inches of coal is left as the roof. The rock above the weak clay is a shale, which also breaks readily. The floor is fireclay.

METHODS OF MINING

Room-and-pillar methods of mining are used exclusively throughout the entire field. In some places the workings are divided into panels, and in others they are not. In fact, both systems are frequently followed in the same mine, depending upon the outline of the coal area that is being worked. Where the coal lies fairly flat, rooms are driven both ways from the entries, but where the coal dips they are driven up the slope only, as is always the practice in the western end of the field where the dip averages 4 to 8 per cent. At one mine, under shallow cover, that was visited, the entries and all crosscuts were driven 11 feet wide, and the rooms were 22 feet wide on 36-foot centers and 300 feet long. The room-necks were 12 feet wide and 12 feet long. This was in No. 11 bed, and the coal averaged six feet ten inches thick. At one mine visited in No. 9 bed the coal averaged four feet seven inches in height, and the entries were all 12 feet wide and the rooms were 23 to 24 feet wide either on 33 or 35-foot centers. The entry crosscuts were 12 feet wide, and the room crosscuts were supposed to be 12 feet wide, but would average about 14 feet. The room necks were 12 feet wide for six feet, then widened both ways. At this mine the rooms were all driven on sights and the net extraction was nearly 75 per cent, despite the fact that no pillars were drawn. At another mine in No. 9

bed, the rooms were driven 30 feet wide; 12-foot pillars were left near the crop where the cover was light, but were gradually increased to 18 feet where the cover was greater. The rooms were 300 feet long, and two tracks were laid in each room.

One feature of the mining methods in this field is the general practice of leaving narrow pillars between the room entries. This pillar was noted as being about 10 feet wide in a number of mines, which, in the writer's opinion, is good practice where the cover is not too thick. It also means a higher extraction.

Figures 4 and 5 show pillar coal not being extracted in two mines.

Losses Of Coal

The principal loss of coal is in the room and the entry pillars, as very few of these are recovered. At some mines in No. 9 bed the room pillars are slabbed after the rooms are completed, or else a room or wide crosscut is driven straight through them between the regular crosscuts. The regular crosscuts are driven 60 feet apart, that is, between crosscuts there will be a block of pillar coal 60 feet long, and 14 to 16 feet wide. Driving another wide crosscut or room 22 feet wide through the center of this block of coal means the extraction of slightly over a third of it, and leaves two 19-feet stumps 14 to 16 feet wide. In mines working No. 11 bed no instance was noted of pillars being either robbed or extracted, but this was because the floor of No. 11 is softer and a squeeze is more liable to result.

In No. 12 bed much wider room pillars and heavier barrier pillars are left, as caves and squeezes are difficult to avoid.

The coal lost with impurities is not very much in either bed, but is greater in No. 11 because of the regular dirt bands which have to be discarded. Practically no roof or bottom coal is left except in No. 12, where 15 inches of top coal is left up, of which 11 inches is good coal.

Actual Extraction

At one mine in the eastern end of the field on No. 9 bed, the extraction, based on actual planimeter measurements, is given as 60.2 per cent in 1920 and 57.2 per cent in 1921. At another mine the extraction was given as 78 per cent in 1922, and at a third mine 76 per cent in 1922. At one mine in No. 11 bed near the central part of the field, planimeter measurements of the area worked out from date of opening in 1903 show a total extraction of 64.7 per cent. At another mine between the central and eastern part of the field the chief engineer estimated the recovery as being between 58 and 65 per cent, probably averaging 63 per cent. In the western end of the field one company operating a mine in No. 9 bed gives its extraction as 60.3 per cent in 1920 and 60.7 per cent in 1921. Another company estimates its extraction during the period of operation as 63 per cent, not including boundary pillars.

The extraction from No. 12 bed will probably be about 40 per cent, because of the larger pillars and the loss of top coal. The writer inspected the maps of several small mines working No. 9 bed, and the indications were that their extraction would be considerably less than that of the mines operated by the larger companies. As previously stated, there are a great many small mines in this district.

Taking all the facts into consideration, the writer estimates that the present extraction in the field as a whole is approximately 63 per cent, and the loss is subdivided, as shown in the accompanying table. If many mines were being working No. 11 bed the loss for the bed would be larger than that for No. 9 bed, due to the fact that there is more liability of squeezes resulting from the weaker floor.

AVOIDABLE LOSSES

The surface has no particular value with the exception of a certain area in the western end of the field, where some land is valued at $200 an acre, but most of the land there is slightly rolling and the drainage could not be seriously affected by surface subsidence. In the writer's opinion, if the district be considered as a whole the value of the surface is not a detriment to pillar drawing.

If pillars were drawn, some solid coal would have to be left under small streams where the cover is not thick enough to prevent the water from entering the workings. Solid coal would have to be left under certain buildings and railroads. The possibility of water saturating the overlying beds is probably not serious, although there is said to be some water in the sandstone between No. 11 and No. 9 beds.

In the writer's opinion, the only possible drawback to pillar drawing in No. 9 bed is the possible shattering of the limestone between Nos. 11 and 12 beds. The latter, where workable, would, of course, be lost by drawing pillars in No. 11 bed. The writer thinks that the pillars in No. 9 bed could be pulled if the work were done systematically—that is, before the overlying beds were opened—but the pillars in No. 11 bed would have to be left if No. 11 were worked before No. 12, and even then the mining of No. 11 without damaging No. 12 would be a serious problem.

Losses In Overlying Beds

At present the only loss of coal in overlying beds must occur in one of these three ways: (1) a squeeze in No. 9 bed will and undoubtedly does cause increased difficulty in mining Nos. 11 and 12, and will mean a slight loss of coal, but the only squeezes

Summary of Coal Losses in West Kentucky (2 Beds)

REASON FOR LOSS	Percentage of marketable coal lost in area worked	
	Total loss	Avoidable loss
Coal left on roof and bottom	None	..
Coal lost in room entry, and panel pillars..	32	20
Coal lost in oil or gas well pillars.........	None	..
Coal lost under buildings, railroads, and boundaries	1	..
Coal lost in handling and preparation, underground and surface	3	..
Coal lost due to rolls, thin and dirty areas, and surface streams	1	..
Total loss, per cent	37	20

that occur are where the pillars have been robbed in No. 9, which is not over a large part of the area. (2) Where room pillars are entirely drawn in No. 9 a cave may reach up to No. 11, but this is improbable, and the action would be similar to a squeeze. (3) Any cave from the limestone above No. 11 will mean a loss of No. 12, but so far the limestone roof seems to be strong enough to hold. There may be considerable loss in the future, and the question worthy of very serious consideration, but the immediate loss is probably not great.

The End

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